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THE

TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOLUME XV.

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY.
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THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY held its first meeting on April 8, 1862. By the act of incorporation, which was accepted at this meeting, the SOCIETY OF ARTS was created as a part of the Institute coördinate with the School of Industrial Science.

The objects of the Society are to awaken and maintain an active interest in the sciences and their practical applications, and to aid generally in their advancement in connection with the arts, agriculture, manufactures, and commerce. Regular meetings are held semi-monthly from October to May.

The Society discontinued the publication of the *Abstracts of Proceedings* in 1891, and since then has published its proceedings and the principal papers read at its meetings in the *Technology Quarterly*. The present volume contains the proceedings from October, 1901, to May, 1902, inclusive.

The *Quarterly* contains, also, the results of scientific investigations carried on at the Institute, and other papers of interest to its graduates and friends.

Neither the Massachusetts Institute of Technology nor the SOCIETY OF ARTS assumes any responsibility for the opinions or statements in the papers.

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

Society of Arts.

OFFICERS, 1902–1903

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HENRY S. PRITCHETT.

Secretary of the Society of Arts.

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Editor of the Technology Quarterly.

ROBERT P. BIGELOW.

BY-LAWS.

Objects of the Society.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement and development in connection with arts, agriculture, manufactures, and commerce.

The Society invites all who have any valuable knowledge of this kind which they are willing to contribute to attend its meetings and become members. Persons having valuable inventions or discoveries which they wish to explain will find a suitable occasion in the Society meetings, subject to regulations hereafter provided; and while the Society will never indorse, by vote or diploma or other official recognition, any invention, discovery, theory, or machine, it will give every facility to those who wish to discuss the principles and intentions of their own machines or inventions, and will endeavor at its meetings, or through properly constituted committees, to show how far any communications made to it are likely to prove of real service to the community.

Section I. — Administration.

The immediate management and control of the affairs of the Society of Arts shall be exercised by an Executive Committee, consisting of the President of the Institute and the Secretary of the Society (who shall be members *ex officiis*), and five other members, who shall be elected by the Society of Arts at each annual meeting, to continue in office until other persons have been chosen in their place.

Sect. II. — Duties of the Executive Committee.

The Executive Committee shall elect its chairman, prescribe his duties, and, with the concurrence of the Treasurer of the Institute, fix his compensation when the interests of the Society require that

he should be paid for his services; they may invite any person to preside at any ordinary meeting who is well versed in the subjects to be discussed; they shall appoint the days and times of meeting when not fixed by the Society, and determine the subjects to be considered at the meetings and the mode of conducting the discussions; they may, with the concurrence of the President of the Institute, make such arrangements for reporting and publishing the proceedings of the Society as they may deem best suited to advance its interests; they may receive moneys in behalf of the Society in aid of its objects by subscription, donation, or bequest; they shall make a report of their doings to the Society at its annual meeting and at such other times as a report may be called for by a majority of the members present at any meeting; they shall also make a report of their doings to the President of the Institute prior to the annual meeting, and at such other times as the Corporation may require it. Three members shall constitute a quorum for the transaction of business.

Sect. III. — Duties of the President and Secretary.

1. It shall be the duty of the President of the Institute to preside at the annual and the special meetings of the Society, and also at its ordinary meetings when the Executive Committee does not invite a special chairman to preside.

2. It shall be the duty of the Secretary of the Society to give notice of and attend all meetings of the Society and of the Executive Committee; to keep a record of the business and orders of each meeting, and read the same at the next meeting; to keep a list of the members of the Society, and notify them of their election and of their appointment on committees; and generally to devote his best efforts under the direction of the Executive Committee, to forwarding the business and advancing the interests of the Society. He shall also record the names of the Executive Committee attending each meeting.

Sect. IV. — Funds of the Society.

All the fees and assessments of members, and all moneys received by subscription, donation, or otherwise, in aid of the Society, shall be paid into the treasury of the Corporation, to be held and used for the objects of the Society under the direction of the Executive Commit

tee, and shall be subject to the order of its Chairman, countersigned by the President of the Corporation.

SECT. V. — MEETINGS OF THE SOCIETY.

1. The annual meeting of the Society shall be held at the Institute on the second Thursday in May. The ordinary meetings shall be held semi-monthly, or whenever deemed expedient by the Society or by the Executive Committee, excepting in the months of June, July, August, and September.

2. If from any cause the annual meeting shall not have been duly notified or held as above required, the same shall be notified and held at such time as the Executive Committee may direct.

3. A special meeting of the Society may at any time be called by the Secretary on a written request of ten members. Twelve members of the Society shall constitute a quorum for the transaction of business.

SECT. VI. — MEMBERS AND THEIR ELECTION.

1. Members of the Society of Arts shall be of three kinds — Associate, Corresponding, and Honorary Members.

2. Candidates for Associate Membership shall be recommended by not less than two members, whose signatures shall be affixed to a written or printed form to that effect. Each nomination shall be referred to the Executive Committee, and when reported favorably upon by them, and read by the Secretary, may be acted upon at the same meeting; the election shall be conducted by ballot, and affirmative votes to the number of three fourths of the votes cast shall be necessary for an election.

3. Corresponding and Honorary Members may be elected in the same way, on nomination by the Executive Committee.

4. Associate Members shall pay an admission fee of three dollars before being entitled to the privileges of membership, and an annual assessment of three dollars on the first of October of each year, this sum to include subscription to the *Technology Quarterly and Proceedings of the Society of Arts.*

An Associate Member who shall have paid at any one time the sum of fifty dollars, or annual assessments for twenty years, shall become a member for life, and be thereafter exempted from annual assessments.

A member neglecting to pay his annual assessment for six months after being notified that the same is due shall be regarded as having withdrawn his membership, unless otherwise decided by the Executive Committee, which shall be authorized, for cause shown, to remit the assessments for any one year; and which shall moreover be empowered to exempt particular members from assessments whenever their claims and the interests of the Society make it proper to do so.

Sect. VII. — Election of the Executive Committee and of the Secretary.

1. At an ordinary meeting of the Society, preceding the annual meeting, a nominating committee of *five* shall be chosen, whose duty it shall be to nominate candidates for the Executive Committee, to post a list of the names selected in the office of the Secretary, and to furnish printed copies thereof to the members at or before the time of election.

2. At a meeting at which an election is to take place the presiding officer shall appoint a committee to collect and count the votes and report the names and the number of votes for each candidate, whereupon he shall announce the same to the meeting.

3. A majority of the votes cast shall be necessary to an election.

4. In the first organization under these By-Laws, the Executive Committee may be elected at an ordinary or special meeting.

5. Vacancies in the committee occurring during the year may be filled by the Society at an ordinary meeting.

6. The Secretary shall be elected by the Society, on nomination by the Executive Committee, at each annual meeting of the Society, or, in case of a vacancy during the session, at such other time as the Executive Committee may appoint; and he shall be reëligible in the same way at the pleasure of the Society.

7. The compensation of the Secretary shall be fixed from year to year by the Executive Committee with the concurrence of the Treasurer of the Institute.

Sect. VIII. — Committees of Arts.

1. The Members of the Society of Arts may be enrolled in divisions, under the following heads, according to the taste or preference of

the individual; each division to constitute a committee upon the subjects to which it appertains:

(1) On Mineral Materials, Mining, and the Manufacture of Iron, Copper, and other Metals.

(2) On Organic Materials — their culture and preparation.

(3) On Tools and Implements.

(4) On Machinery and Motive Powers.

(5) On Textile Manufactures.

(6) On Manufactures of Wood, Leather, Paper, India Rubber, and Gutta Percha.

(7) On Pottery, Glass, Jewelry, and works in the Precious Metals.

(8) On Chemical Products and Processes.

(9) On Household Economy; including Warming, Illumination, Water-Supply, Drainage, Ventilation, and the Preparation and Preservation of Food.

(10) On Engineering, Architecture, and Ship-building.

(11) On Commerce, Marine Navigation, and Inland Transportation.

(12) On Agriculture and Rural Affairs.

(13) On the Graphic and Fine Arts.

(14) On Ordnance, Firearms, and Military Equipments.

(15) On Physical Apparatus.

2. Any member may belong to more than one of the above-named Committees of Arts, but shall not at the same time be eligible as chairman in more than one.

3. It shall be competent for each Committee of Arts, of ten or more members entitled to vote, to organize; to elect annually in October, or whenever a vacancy shall occur, a chairman; to appoint its own meetings; and to frame its own By-Laws, provided the same do not conflict with the regulations of the Society of Arts.

Sect. IX. — Amendment and Repeal.

1. These By-Laws may be amended or repealed, or other provisions added, by a vote of three fourths of the members present at any regular meeting of the Society; provided that such changes shall have been recommended and approved in accordance with the By-Laws of the Corporation (see extract from By-Laws of Corporation as

printed below) and presented in writing at a preceding meeting of the Society.

2. These By-Laws shall take effect immediately after their approval by the Corporation and adoption by the Society, and all previous By-Laws are hereby repealed.

As amended December 9, 1897.

EXTRACT FROM THE BY-LAWS OF THE CORPORATION.

SECT. VI. — There shall be a Committee on the Society of Arts consisting of five members, appointed at the annual meeting of the Corporation, to hold office for one year, who shall have the general charge and supervision of the organization and proceedings of the Society, subject to the approval of the Corporation. It shall be their duty, in connection with a committee chosen by the Society, to frame By-Laws for the government of the Society, which shall take effect when adopted by the Society and approved by the Corporation.

February, 1894.

LIST OF MEMBERS.

DECEMBER, 1902.

Members are requested to inform the Secretary of any change of address.

THE CORPORATION.

Blake, Francis . . . . . Auburndale, Mass.
Cabot, Samuel . . . . . 70 Kilby Street, Boston, Mass.
* Carson, Howard A. . . . . 20 Beacon Street, Boston, Mass.
Choate, Charles F. . . . . 50 State Street, Boston, Mass.
Draper, Ebin S. . . . . Hopedale, Mass.
** Endicott, William . . . . . 32 Beacon Street, Boston, Mass.
Fairchild, Charles . . . . . 29 Wall Street, New York, N. Y.
Felton, Samuel M., Chicago & Alton R. R., Monadnock Building, Chicago, Ill.
Fish, Frederick P. . . . . 40 Water Street, Boston, Mass.
* Freeman, John R. . . . 812 Banigan Building, Providence, R. I.
Gardiner, George A. . . . . 22 Congress Street, Boston, Mass.
Higginson, Francis L. . . . . 50 State Street, Boston, Mass.
Hubbard, Charles W. . . . . 133 Essex Street, Boston, Mass.
Jackson, Charles C. . . . . 24 Congress Street, Boston, Mass.
Lee, Elliot C. . . . . Brookline, Mass.
Lincoln, William H. . . . . 92 State Street, Boston, Mass.
Livermore, Thomas L. . . . . 12 Ashburton Place, Boston, Mass.
Lothrop, Thornton K. . 27 Commonwealth Avenue, Boston, Mass.
Lovering, Charles L. . 53 State Street, Room 843, Boston, Mass.
* Lowell, A. Lawrence . . 171 Marlborough Street, Boston, Mass.
* Lowell, Percival . . . . . 53 State Street, Boston, Mass.
Merriam, Charles . . . . . 50 State Street, Boston, Mass.
Mills, Hiram F. . . . . Broadway, Lowell, Mass.
* Munroe, James P. . . . . 179 Devonshire Street, Boston, Mass.

Paine, Charles J. . . . . Sears Building, Room 613, Boston, Mass.
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Pritchett, Henry S. . Mass. Institute of Technology, Boston, Mass.
Putnam, William L. . . . 50 State Street, Room 59, Boston, Mass.
* Rotch, A. Lawrence . . . . . 53 State Street, Boston, Mass.
Sewell, J. B. . . . . .
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Stockton, Howard . . . . . 87 Milk Street, Boston, Mass.
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Weld, Charles G. . . . . 70 Kilby Street, Boston, Mass.
Wheeler, Alexander S. . . . 72 Marlborough Street, Boston, Mass.
Whitney, David R. . . . . 85 Devonshire Street, Boston, Mass.

On the part of the Commonwealth.

His Excellency the GOVERNOR.
The Honorable the CHIEF JUSTICE OF THE SUPREME COURT.
The Honorable the SECRETARY OF THE BOARD OF EDUCATION.

---

* Associate Member, Society of Arts.
** Life Member, Society of Arts.

LIFE MEMBERS.

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Whitaker, Channing . . . . . Lowell, Mass.
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PROCEEDINGS OF THE SOCIETY OF ARTS.

FORTIETH YEAR, 1901–1902.

BOSTON, October 10, 1901.

THE 555th regular meeting of the SOCIETY OF ARTS was held in the Rogers Building, Room 11, on this day at 8 P.M., President Pritchett presiding. One hundred and ninety persons were present.

The records of the previous meeting were read and approved. The following gentlemen were elected to Associate Membership: Henry A. Morss, Russell Suter, and Frank J. Huse. At the conclusion of the business, Naval Constructor William J. Baxter, U. S. N., was introduced and spoke on "The 'Olympia': a general description of this famous ship, and a discussion of the development of cruisers during the past, and the tendency to future progress."

The "Olympia" was chosen as the standard for comparing the cruisers of the past with those of the future. She was designed nine years ago. The speed developed on her trial trip was unprecedented for a ship of her displacement and class. She has successfully met

every demand which peace and war conditions have placed upon her. In the remodeling which she has lately undergone, it has been neither practicable for financial reasons, nor desirable from strategic reasons, to expend enormous sums of money in making her absolutely "up to date."

The building of the "Olympia" was authorized by Act of Congress, September 7, 1888. The vessel was launched November 5, 1892, and placed in commission February 5, 1895. She was placed out of commission at Boston Navy Yard, November 8, 1899, and will probably be recommissioned during the month of December, 1901. Her value on the morning of the fight at Manila Bay was not far from $3,500,000.

The armored cruisers now building show a great advance in every direction. A comparison of the dimensions, engine-power, speed, coal capacity and armament was made. The present tendency is for the battleship and the cruiser to be combined into a new type which shall unite the speed of the one with the power of the other, limited in size only by the shallowness of our harbors.

Under all ordinary sea conditions every ship must have ample flotation, strength, and stability, and furthermore must be capable of making the greatest speed with the least expenditure of power; with a warship the problem becomes more complicated, as the conditions which may arise in battle must also be considered. In the design of cruisers, the determination of the armament is of the highest importance and governs the outboard design of the whole ship, such as smoke pipes, comfort and beauty. Everything above the water line, outside and inside the ship, must give way to effective use of the guns. Whereas the fashion in guns varies like all other fashions, the shape of the underwater hull once decided upon and built is unalterable, hence the necessity of exercising the greatest care upon a ship's lines.

In this connection the speaker emphasized the value of the experimental tank; for instance, the one in Washington, for studying new and untried models of cruisers and other ships. This was beautifully exemplified in the case of the five latest battleships, whose lines were drawn with the utmost skill and care, based upon previous experience. A few tests in the experimental tank with models gave information which will result in the development of 19 knots with 2,000 less horse power than would have been required with the first

set of lines. After the ship's model has been determined, the necessary strength, water-tightness, safety and stability must be provided for. The inner structure of a steel ship is designed upon the same girder principles as those of bridges, beams, etc., but complicated by the conditions governing safety at sea, and in warships still further by the unusual injuries to which such crafts are liable. For better protection against injury, water-tight compartments are used. The "Olympia" has 145 such compartments.

Referring to sheathing, Mr. Baxter said that it had been shown that an anti-fouling paint successful under one set of conditions is unsuccessful under others; for example, the paint used on transatlantic liners with much success is not efficient on vessels cruising in the tropics. Moreover, it seems probable that warships of large tonnage will not be sheathed in the future, as such vessels should be docked at least once a year for the purpose of overhauling and examining the underwater portions of the hull and machinery, no matter whether the vessel be sheathed or not.

The importance of electricity in the modern warship was rapidly sketched. It is used for lighting, for search lights, ammunition hoists, turning turrets, and signaling. There is always a fire alarm system and a telephone system. The very important questions of ventilation and drainage were considered. In closing, the speaker gave a short history of the Boston Navy Yard and its probable position in the near future. "A Navy Yard is more than a shipyard; it is a mammoth workship which contains not only shops and ships, dry docks and all other appurtenances for the repair of all parts of all types of warships, and therefore capable of building ships, it is also a storehouse which distributes all the necessities of a ship, from the ammunition of 12″ guns to the food and clothing of the men who load and fire them. The multiplicity of demands would be tiresome to recapitulate, but it may be well to call attention to a fact not generally recognized in this country, that a Navy Yard, capable of caring for three battleships under emergency conditions, is capable of performing any service of any kind for any merchant vessel and of building any type of vessel."

The thanks of the Society were most heartily extended to Captain Baxter for his able address.

BOSTON, October 24, 1901.

The 556th regular meeting of the SOCIETY OF ARTS was held in the Rogers Building, Room 11, on this day at 8 P.M., Professor George F. Swain presiding. Sixty persons were present.

Professor William Z. Ripley, Expert Agent on Transportation, U. S. Industrial Commission, addressed the Society on "Present Conditions of American Railroads as Compared with the Period of Depression, 1893 – 1897." The main purpose of the paper was to contrast the present phenomenal prosperity of American Railroads with conditions prevalent during the period of depression, 1893 to 1897, as well as to compare present prosperity with similar periods at an earlier time. The present prosperity, as manifested in an enormous volume of traffic — traffic, moreover, of a higher grade — and finally as resulting in very large net earnings, dividends and surplus, were outlined at length. The great changes in methods of operation, particularly in the train load, were also described. It was shown that more improvement in this respect has characterized the last three years than at any similar period in our history. The paper concluded with a discussion of the bearing of these improvements in operation upon the Interstate Commerce Commission.

BOSTON, November 13, 1901.

The 557th regular meeting of the SOCIETY OF ARTS was held on this day, in the Chemical Lecture Room, Walker Building, at 8 P.M. President Pritchett presided. One hundred and sixty persons were present.

The report of the previous meeting was read and approved. The following persons were elected to Associate Membership: Arthur N. Mansfield, Albert Chittenden, Paul McJunkin. At the conclusion of the business, Professor Arthur A. Noyes was introduced and gave an experimental lecture on "The Importance of Catalytic Agents in Chemical Processes."

Catalysis was defined as the acceleration of chemical reactions by substances which are not consumed in reaction, *i. e.*, they are present at the end of the reaction. The catalytic agents were classified as follows:

1. Carriers.
2. Absorbent contact agents.
3. Electrolytic " "
4. Water.
5. Acids, bases, and salts in solution.
6. Organic colloids, enzymes.
7. Inorganic colloids.

These classes were considered from the experimental and the theoretical standpoint.

Class I. By carriers are meant catalytic agents, which form an indeterminate compound with one of the reacting substances, and thus enable it to react more readily with the other substance.

There is no accepted theory of carrier action. It is known, however, that the rate at which any reaction takes place is proportional to the concentration of each of the substances involved.

Class II. Many solid substances which have the power of absorbing gases cause rapid reaction by mere contact. For example, hydrogen peroxide, H_2O_2, is ordinarily a stable compound, but when mixed with platinum black or bone black there is a quick reaction, the peroxide breaking up into H_2O and O.

$$2H_2O_2 = 2H_2O + O_2.$$

Metals in contact with gases often accelerate any reaction. If a platinum crucible be heated to redness and the flame be extinguished, the platinum crucible continues to glow. The gas is sufficiently concentrated by the platinum to undergo combustion and thus preserve the high temperature. Other experiments illustrating this class of catalytic reactions were given.

There are two theories to explain the action of absorbent contact agents: (1) That the metals really act as carriers; (2) that the substances cause the reactions by increasing the concentration of the reacting gases.

Class III. Electrolytic contact agents. Many metals do not react in solution until another metal is brought in contact with them. This class was illustrated by a number of experiments, one of them being the reaction of tin on hydrochloric acid. On placing the Sn in HCl no reaction followed; on adding a piece of platinum or platinum chloride ($PtCl_6$), however, the tin immediately reacted, forming stan-

nous chloride and hydrogen, the platinum remaining in its original condition.

$$PtSn + 2HCl = SnCl_2 + H_2 + Pt.$$

All reactions of this class may be explained on the electrolytic theory of dissociation. The tin and platinum form a cell, with Sn + and Pt —; the free negative chlorine ions move towards the + Sn, and unite, forming neutral stannous chloride; the hydrogen is attracted to the platinum, where it is absorbed or evolved as gas.

Class IV. Action of water. Many substances when carefully dried either do not react, or else to a very slight extent, whereas the reactions take place readily, often very energetically, when water is present. Among such reactions is that of ammonium chloride, which when dry is not decomposed even at the temperature of 350° C. In the ordinary condition, however, the dissociation takes place readily, ammonia and hydrochloric acid being formed.

$$NH_4Cl = NH_3 + HCl.$$

A very interesting experiment was performed with burning sodium placed in an atmosphere of dry chlorine gas. On introducing the sodium into the tube no reaction took place between the sodium and the chlorine, and consequently the burning sodium was quickly extinguished. On repeating the experiment, using moist chlorine gas, sodium chloride was formed with the evolution of sufficient heat to cause the sodium to glow brilliantly.

There is no satisfactory explanation of the action of water in such reactions, except in the case of solutions. In the latter it is assumed that water causes dissociation of the salt into its ions, and that the reactions take place between these ions.

Many experiments were shown in illustration of Case V, among them the conversion of cane sugar to glucose and fructose. The laws governing such reactions are: (1) the different acids have different effects at the same concentration on the rate of hydrolysis; (2) the relative effects of different acids on different reactions are the same; (3) the power which acids have of accelerating reactions varies directly as the electrical conductivity.

Owing to the lateness of the hour classes VI and VII were considered very briefly. Experiments were shown illustrating the great importance of unorganized ferments and enzymes in the processes upon which life depends.

BOSTON, November 26, 1901.

The 558th regular meeting of the SOCIETY OF ARTS was held in the Walker Building on this day at 8 P.M., Professor Cross presiding. Three hundred and sixty persons were present.

The report of the previous meeting was read and accepted. The following persons were elected to Associate Membership: Dr. Samuel P. Mulliken and Charles E. Farrington.

Mr. Alex. E. Wurts, Manager of the Nernst Lamp Company, addressed the Society on "The Development of the Nernst Lamp in America." The hall was lighted with Nernst lamps, comparative tests between the Nernst and incandescent lamps were made at the lecture table, and the details of the lamp were exhibited and fully explained.

A full report of the lecture may be found in the "Transactions of the American Institute of Electrical Engineers" for June and July, 1901. A reprint of this paper is on the files of the Society.

An interesting discussion followed, in which Professor Elihu Thomson participated.

The thanks of the Society were most heartily given to Mr. Wurts for his very able and interesting paper.

BOSTON, December 12, 1901.

The 559th regular meeting of the SOCIETY OF ARTS was held on this day at the Walker Building, at 8 P.M., President Pritchett presiding. Over four hundred persons were present.

Mr. M. H. Merrill, Westinghouse Elect. & Mfg. Co., Mr. Andrew Raeburn, Westinghouse Church Kerr Co., and Mr. Henry P. James, with Factory Mutual Fire Insurance Co., were elected to Associate Membership.

Mr. Cornelius Vanderbilt, of New York, was introduced and gave a very able and comprehensive paper on "The Development of Locomotive Boilers," with particular reference to the "Vanderbilt" boilers. A *résumé* of this paper by Mr. Vanderbilt has been received and placed on file.

The thanks of the Society were most heartily given to the speaker.

GEORGE V. WENDELL, *Secretary.*

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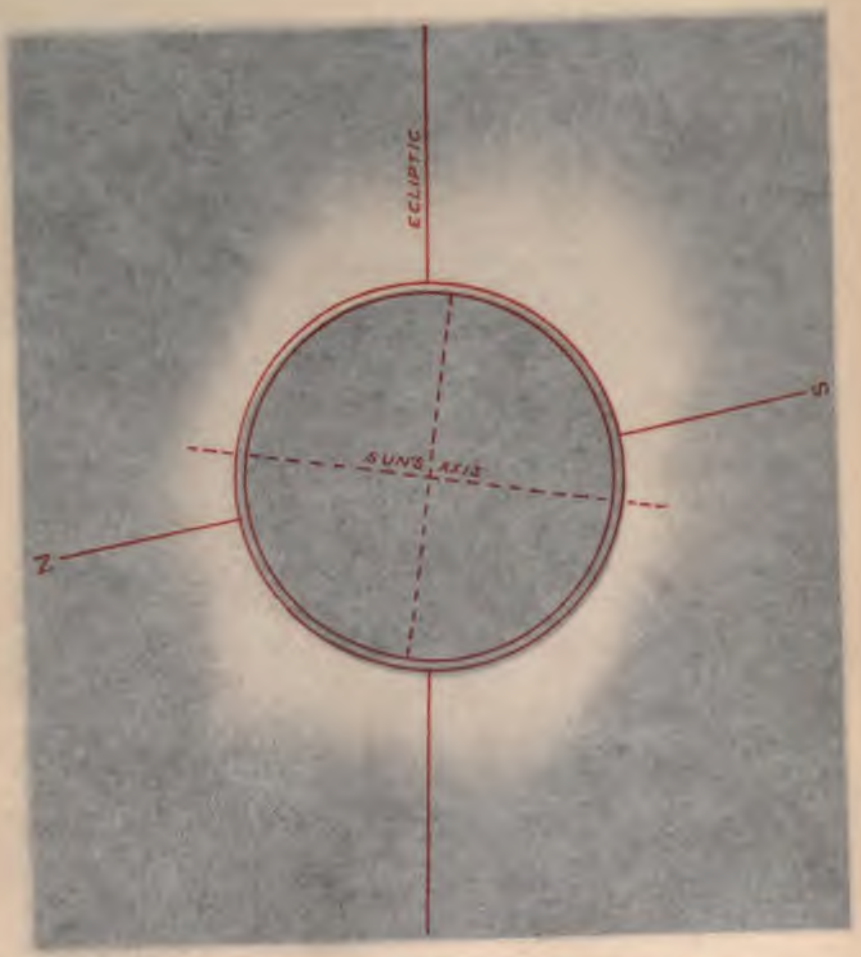


HELIOTYPE FROM PHOTOGRAPH OF CORONA, BY HARRISON W. SMITH.

Enlarged to one and one-half diameters. Exposure 20 seconds.

REPORT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY ECLIPSE EXPEDITION TO SUMATRA IN 1901.

By ALFRED E. BURTON, S.B.

The President, with the approval of the Corporation of the Massachusetts Institute of Technology, decided in January, 1901, to send an expedition to Sumatra to observe a total eclipse of the sun on May 18 of that year, and two thousand dollars were appropriated from the Austin Fund towards defraying the necessary expenses.

The Eclipse of May 18, 1901, was of an exceptional character, the duration of totality being more than six minutes. The track of the shadow extended from Madagascar across the Indian Ocean and through the islands of Malaysia. The west coast of Sumatra furnished the most accessible points of observation. The one unfavorable thing in connection with this eclipse was that the path of totality passed over regions of nearly continuous cloudiness and rain. The weather records of the past years, prepared by the Dutch Committee on the Eclipse, gave some hopeful indications of a clear sky at midday near Padang, in Sumatra, during the month of May.

The writer was placed in charge of the expedition; the other members were Mr. George L. Hosmer, Instructor in the Civil Engineering Department; Mr. Harrison W. Smith, Instructor in the Department of Physics; and Mr. Gerard H. Matthes, Class of '95, Assistant Hydrographer United States Geological Survey; the last-named gentleman is a native Hollander and a graduate of the Civil Engineering Department at the Institute.

As the expenses of the expedition would necessarily be much greater than the appropriation, the writer undertook to secure additional funds from friends of the Institute, and he desires to acknowledge his indebtedness to Mr. John C. Phillips, Mr. Francis Blake, Mr. A. Lawrence Rotch, Mr. Andrew H. Green, and others, whose assistance made the undertaking possible.

President Pritchett decided at the outset that the Institute expedition should try to do some scientific work not directly dependent upon the condition of the weather at the moment of the eclipse, and through the kindness of the Superintendent of the United States Coast and Geodetic Survey, the party was supplied with the half-second pendulum apparatus, which had already been used extensively in this country and in Europe for determining the relative values of the force of gravity at many different points. We were commissioned to swing these pendulums at a new station on the equator

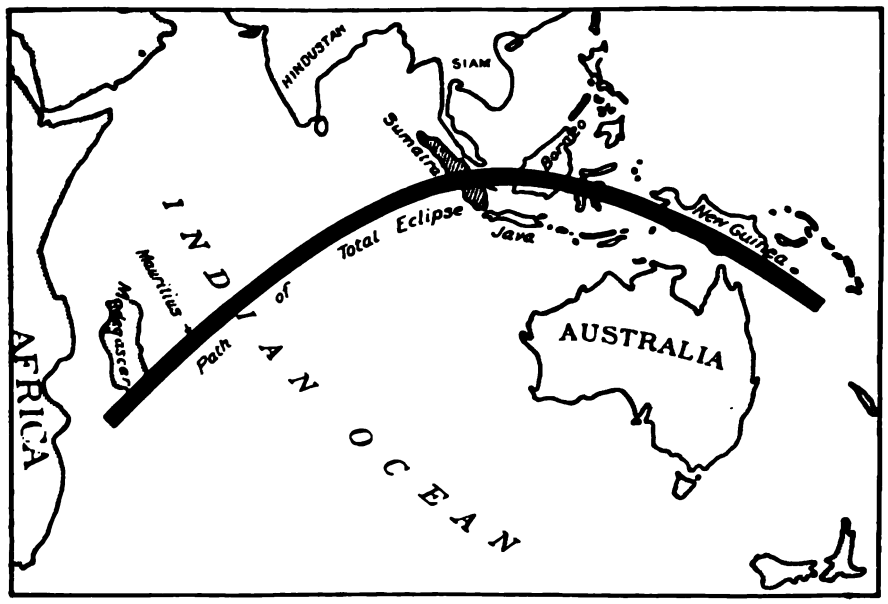


FIG. 1.—PATH OF THE ECLIPSE.

in the Island of Sumatra, thus adding to the data for determining the figure of the earth. We were also asked to swing the pendulums at a station in Singapore which had been previously occupied by a United States government party using another type of pendulum. This last observation was intended to tie together the many results already obtained by these two different types of instruments. It was planned that we should carry on a set of magnetic observations in connection with a general scheme for determining the amount of magnetic disturbance occasioned by the passage of the shadow of the moon over the earth. This work was to be done under the

directions of Dr. Bauer, of the United States Coast and Geodetic Survey, and the instruments to be used were a Kew magnetometer and a Barrow dip circle.

The plan in connection with the eclipse proper included the determination of the times of the four contacts, the photographing of the corona, as well as that portion of the sky immediately surrounding the sun, and the obtaining of direct photographic records of the shadow bands. The outfit used for this part of the work consisted of a 5-inch equatorial telescope, an astronomical transit, a chronograph, and three chronometers for the time observations; three large cameras of 11 feet focal length, and one of 40 inches, with their equatorial mounting, for the photographic work; and six cameras of original design for recording the shadow bands. The astronomical instruments were from the Geodetic Observatory of the Institute; the cameras and shadow band boxes were made at the Institute, under the direction of Mr. Harrison W. Smith; the lenses for the large cameras were ground by Mr. Carl Lundin, of Cambridge, and two of them were generously loaned to us by Professor E. C. Pickering, of the Harvard College Observatory.

It was expected that Mr. A. Lawrence Rotch would join the party at Sumatra with a meteorological outfit, and therefore no instruments of this character were included in our plan.

The route decided upon for reaching Sumatra was the one which presented the least difficulties in the transportation of instruments. The entire equipment weighed about four tons, and included many instruments of delicate construction, which might be easily damaged and thrown out of adjustment by much railroad transportation. Everything was shipped by the Metropolitan Steamship Line from Boston to New York, and then direct to Genoa by steamer "Werra," of the North German Lloyd; there connection was made with the steamer "Koningin Regentes," of the Dutch Mail, sailing to Padang, west coast of Sumatra, with stops for coaling at Port Said and at Perim near the mouth of the Red Sea. This route was not only the safest in the matter of transportation of instruments, but was also the cheapest, as the Dutch Steamship Line gave special rates to astronomical parties and carried our freight free. It proved to be a most comfortable and enjoyable method of traveling, as these Dutch steamers are better equipped for tropical conditions than most of the lines running to the Indies. We also had the

good fortune to meet on the "Koningin Regentes" the members of both the Holland and the two English astronomical expeditions. The Hollanders were Professor A. A. Nijland, Professor W. H. Julius, Mr. J. H. Wilterdink, and Mr. J. B. Hubrecht; the English observers were Mr. and Mrs. H. F. Newall, of Cambridge Observatory; Mr. F. W. Dyson, of the Royal Observatory, Greenwich, and Mr. J. J. Atkinson. This steamer voyage was one of the pleasantest parts of the trip, and from the genial Hollanders we received our introduction to the manners and culinary art of the East Indies. The courtesy of Captain Kotting afforded us the opportunity to charge our storage batteries from the ship's dynamo before reaching Padang.

On April 6 we sailed into Emmahaven, the port of Padang, thus ending the voyage which began in New York on February 24.

We were met at Emmahaven by the United States Consular Agent, Mr. C. G. Veth, who had already arranged for the accommodation of our party. Mr. Veth was most helpful to us during the whole period of our stay. On April 7 we paid our official visit to the Governor of Sumatra. Here we made the acquaintance of Major J. J. A. Müller, in charge of the survey of the island, and Mr. R. Delprat, Director and Engineer of the State Railroads. Everything possible in the way of courtesy and hospitality was shown to us by these gentlemen. After consultation with Mr. Delprat, the writer decided to visit the coal mines at Sawah Loento in search of a site for an observing station. On April 8, armed with a letter of introduction to Mr. van Lessen, Chief Engineer of the Mines, Mr. Matthes and the writer journeyed a hundred miles into the interior. At Sawah Loento we found a neat little hotel, newly erected for the accommodation of visitors to the mines, and south of the hotel, and not much more than a mile away, we found a favorable spot for the erecting of piers and houses for instruments. Labor and material for building appeared in abundance, and with Mr. Matthes for interpreter, we soon came to a satisfactory and definite settlement. Two days later we moved our entire outfit by rail to Sawah Loento; transportation for both passengers and freight was furnished free. Through the kindness of the "Comptrolleur," Mr. Sieburgh, bands of convict laborers were assigned to us, roads were extended to our station and a site for the building was cleared and leveled. Brick and cement for the piers and bamboo for the houses had to be

carried up by water-buffalo carts and coolie laborers. Six thousand bricks and thirteen barrels of cement were required for the piers alone. It is not wise, or even possible, to rush work under the equator, and it was not until April 17 that the masonry work began. Our best workmen, both in brick laying and in house building, were hired Chinamen, the native Malay not taking kindly to this sort of labor.

FIG. 2. — WORK AT M. I. T. STATION, APRIL 17TH.

On account of the excessive rain it was necessary to build the houses before any of the instruments could be transported to the station. The camera house was completed April 22; the transit and pendulum house on April 28; the instruments were brought to the station from the Sawah Loento depot on April 29. During the first week in May, Mr. Smith's camera frame was placed in position, the focal length of the lenses determined, the cameras attached to the frame, and the polar axis adjusted in position on the tops of the piers.

Mr. Hosmer completed a set of pendulum observations on May 8, a full account of which will be found in his appended report.

As it was desirable that the magnetic observations should be made at a point free from any accidental local attraction, it was decided to build a special magnetometer hut on an adjacent mountain. This magnetometer shelter was built by the native Malays of bamboo and thatched with grass, no nails or metal of any kind being used in its construction. The hut could only be reached by a difficult climb,

FIG. 3.—GENERAL VIEW OF THE STATION ON THE DAY BEFORE THE ECLIPSE.

and there was absolutely no danger of the work being disturbed by passers-by. Mr. Hosmer made the observations with the magnetometer, and a full account of these will be found in his report.

The Eclipse Station of the English Astronomical Party, in charge of Mr. H. F. Newall, of Cambridge, was established at a point about a mile northwest of the mines and three miles north of our station. We were able to see from one station to another, and time signals were sent to Mr. Newall from our station on several days previous to the eclipse. Dr. S. A. Mitchell, of the Naval Observatory, located

Scale 1:20000

Contour Interval 50 Meter

FIG. 5.—MAP SHOWING LOCATION OF ECLIPSE STATIONS NEAR SAWAH LOENTO.

M. I. T. Eclipse Station marked by red circle; the Magnetometer Stations, by red crosses.

his instruments a short distance to the west of us and on the same ridge. The accompanying map, Figure 5, shows the relative positions of these different parties at Sawah Loento. We were quite

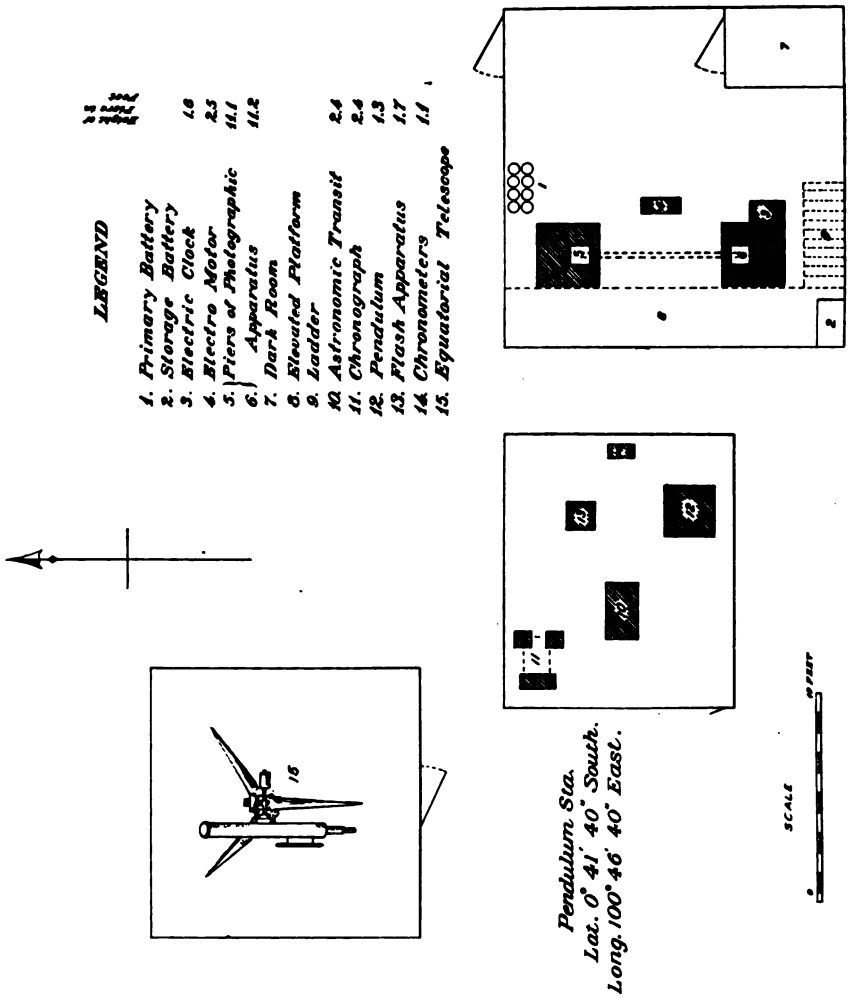


FIG. 4. — PLAN OF ARRANGEMENT OF THE APPARATUS.
Altitude of pendulum station, 1246 feet.

near neighbors, and during the month of preparation were able to be of some mutual assistance.

Not until the evening before the eclipse was everything in readiness for the work in hand; there had, fortunately, been enough clear days and nights for the necessary adjustments.

The hill on which our station was situated was called in the Malay language "Boekit Koebang Sirakoek."

Noon was the hour of totality. During our days of preparation we had noted but few times when the weather was favorable at this hour. The morning of the 18th of May was very hazy, with low clouds hanging over the mountains and drifting through the valleys. At ten o'clock the sky cleared, and at the time of the first contact was everything that could be desired. Soon after, light patches of cloud

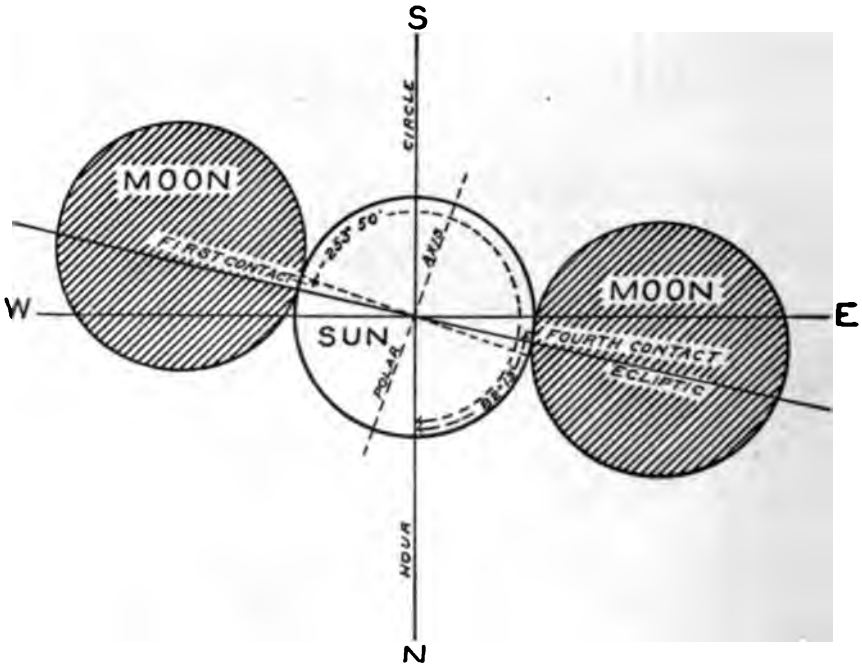


FIG. 6. — DIAGRAM SHOWING POSITIONS OF POINTS OF FIRST AND FOURTH CONTACTS.

began to blow across from the northeast, but the sun was never very much obscured. During the whole period of totality the corona was plainly visible to the naked eye, and at moments was very clearly defined. This was not the case at other points close at hand; at our magnetometer shed, which was only half a mile distant, the clouds were so thick that even the times of the second and third contacts could not be noted, and just before totality a colored halo was seen about the sun.

Mr. Smith carried out the prearranged plan for the exposure of

the photographic plates without mishap or accident. After developing the plates, he found that he had an excellent negative of half-second exposure near the moment of the second contact, showing the prominences, and a very clear negative of twenty seconds' exposure, showing the corona. Half-tone and heliotype reproductions from enlargements of these plates are presented with this report. A detailed account of the photographic work is also given by Mr. Smith. The photographic reproductions fail to do justice to the sharpness and clearness of detail in the original negatives.

Observations for the times of the four contacts were made by the writer. The sky was sufficiently clear at these moments to make it possible to obtain exact records.

Time Observations.

Using the latitude and longitude of our station as given on the topographical map of Sumatra, and assuming that the longitude of Padang was 100° 20′ 32″ † east of Greenwich, we computed the times of the four contacts from the elements given in the American Nautical Almanac. The longitude of Padang has been obtained simply by transfer of chronometers, and is therefore not to be entirely depended upon.

The observations were made with an equatorial telescope, with 5-inch objective, and were recorded on a chronograph by means of an electric key, held in the hand of the observer.

TABLE OF PREDICTIONS AND OBSERVATIONS.

Greenwich Mean Time.

May 17, 1901.

	Position Angle.	Prediction, G. M. T.			Observed.		
		h.	*m.*	*s.*	*h.*	*m.*	*s.*
First contact	253° 50′	16	05	19.6	16	05	01.2*
Second contact . . .		17	39	16.4	17	38	59.1
Third contact . . .		17	44	58.1	17	44	47.0
Fourth contact . . .	82° 13′	19	17	21.4	19	16	59.7

† The longitude of Padang here given is from the American Ephemeris and Nautical Almanac for 1901. We understand that Major Müller gives the longitude as 100° 21′ 55″ E. This value will reduce the differences between observed and predicted times of contact.

* See foot-note on page 18.

Local Mean Time.

May 18, 1901.

Number of Contact.	Predicted				Observed				Difference.
		h.	*m.*	*s.*		*h.*	*m.*	*s.*	*s.*
I	A.M.	10	48	26.3	A.M.	10	48	07.9*	— 18.4
II	P.M.	12	22	23.1	P.M.	12	22	05.8	— 17.3
III	P.M.	12	28	04.8	P.M.	12	27	53.7	— 11.1
IV	P.M.	2	00	28.1	P.M.	2	00	06.4	— 21.7

Predicted length totality, 5*m*. 41.7*s*. Observed length totality, 5*m*. 47.9*s*.

The second and third contacts were both observed with an open eyepiece, without the shaded glass, and the writer feels sure that the observed period of totality cannot be in error by more than one second.

The fourth contact was observed with a clear sky, and is the most precise of the series.

Mr. Matthes took charge of the shadow band work, and his written report is here given:

REPORT ON THE OBSERVATION OF SHADOW BANDS.

By GERARD H. MATTHES, S.B.

In order to observe the shadow bands, a large white sheet was stretched out in the centre of the area occupied by the shadow band cameras. Two laths, each 10 feet long, made of split bamboo, were used to indicate the direction of movement of the lines. The six shadow band cameras were arranged in two rows of three each, running east and west. The boxes[1] were placed with their main axes as follows, the directions given being those in which their respective shutters moved:

First row, exposed before second contact:
No. 1, E. to W.
No. 2, S. to N.
No. 5, S. E. to N. W.

Second row, exposed after third contact:
No. 3, S. W. to N. E.
No. 4, S. to N.
No. 6, E. to W.

In order to prevent shifting during the instant of exposure, the cameras were held in place by small piles of brick disposed around them.

* The exact moment of first contact was missed, but a record was made on the chronograph and the angular length of the arc of contact estimated; when the arc of contact just before the fourth contact appeared of the same length, another record was made on the chronograph, and the interval of time between this last record and the fourth contact was then applied as a correction to the first observation.

[1] The construction of the shadow band boxes is described in Mr Smith's Report on Photographic Work.

The operation of exposure consisted, first, of uncovering the camera; second, of pulling the string liberating the shutter; third, of covering up the camera.

The cardboard covers, with which each camera was provided, were removed about five minutes prior to the advent of the bands and replaced immediately after exposure. The exposures were made at a signal given by me to Messrs. W. van der Valk, C. van Overeen, and A. van Eugen, who courteously had offered their services for this purpose.

A few seconds before the second contact, dim shadow bands became visible, extending in a north-south direction, and moving from east to west. Owing, probably, to the cloudiness at that instant, the bands were indistinct, and their duration, it is estimated, did not exceed five seconds. The cameras in the first row were exposed in succession, their order being No. 1, No. 5, and No. 2. Cameras No. 1 and No. 5 were duly exposed, but by the time the shutter of No. 2 moved, the bands had already disappeared.

Immediately after the third contact the shadow bands became again visible.

The bands were well defined, and upon their appearance I gave the signal for the three remaining cameras to be exposed simultaneously. The bands at this time remained visible for about twenty seconds, increasing for a while in intensity, then fading gradually as the sunlight became brighter.

I had opportunity to verify the direction of the lines, and found it to agree exactly with that obtained at the previous observation.

Of the cameras, it was found that No. 4 failed to work properly, and that the shutter of No. 6 did not quite close.

As a summary of the eye observations, made at both times, the following statement may be made:

The bands appeared to be one-half inch wide, very sinuous and from two to three inches apart, their general appearance bearing a striking analogy to the ripple marks on a sandy beach.

Their motion was both vibratory and translatory, *i. e.*, the sinuosities were seen to undulate rapidly, while at the same time the band as a whole progressed from west to east. The fact that the bands were in constant vibration, together with the apparent merging of bands into each other, made it exceedingly difficult to gain an idea of their velocity of translation. It was further observed that the bands would disappear, new bands appearing in their places with great frequency. In short, while the character of the bands themselves was easily observed, also that the bands moved from west to east, *i. e.*, at right angles to their general direction, the determination of their velocity seemed well-nigh impossible.

From the above it is evident that to measure the velocity of any one band in particular would be attended with considerable difficulty, owing to the uncertain nature of its movements. Nor would such a determination, if made, be at all representative of the movement of the shadow bands as a whole. Obviously, the latter velocity is the only one of consequence. As to its value, I find it impossible, however, to make an estimate that would rest on any degree of conviction.

In addition to making these observations, Mr. Matthes made a plan, showing the location of the different instruments, traced from the government topographical survey the accompanying map of Sawah Loento and the surrounding country, and it was through his services as interpreter that we were enabled to keep in intelligent communication with our official friends, and to profit by their kindness and assistance.

On the evening of May 18th we received telegraphic reports of the results obtained by the different astronomical parties. There was

a general tone of disappointment. It was from the station of Fort de Kock alone that we received news of a perfectly clear sky. A few days after, a more hopeful view of the situation was taken by several of the parties; the developed plates revealing more than was anticipated.

There were gathered together on the west coast of Sumatra, in the northern half of the shadow's track, some eleven different eclipse expeditions. The accompanying map will indicate the positions occupied by these parties. The Holland Party was located near Painan, on the coast, almost exactly on the central line of the eclipse; near them, on the Island of Aoer Gadang, was the English party from the Greenwich Observatory; at Padang were the Lick Observatory Party, the French and Russian Observers, and several Jesuit Fathers from the Calcutta and Manila Observatories; on the coast near Padang were located the instruments of the Japanese astronomers; at Solok, on the railroad line to the coal mines, was gathered the larger part of the Naval Observatory Expedition; at Sawah Loento there were Mr. H. F. Newall and his English party, Dr. S. A. Mitchell, from the Naval Observatory, and the party from the Massachusetts Institute of Technology; at Fort de Kock, near the northern limit of the shadow's track, observations were made by Dr. W. S. Eichelberger, Dr. Humphreys, and Mr. Peters, of the Naval Observatory Party.

On the day of the eclipse all weather predictions seemed to fail; those places where the indications had been most favorable were then visited with the cloudiest skies; and some spots considered entirely unfit for occupation furnished exceptionally fine weather at the critical moment. Solok was one of the most unfortunate locations, and Fort de Kock the best. Fort de Kock was very near the northern margin of the shadow, but at Padang Panjang, well within the track, where no one had dared risk a location, the conditions were ideal.

After the photographic plates had been developed there was no farther work at Sawah Loento; only to pack our goods and to thank the officials and people in this community for the kind assistance and courtesies extended to us. To Mr. van Lesson, chief engineer of the mines, to the comptrolleur, Mr. Sieburgh, and to Mr. van der Valk, we are much indebted for special help in the construction of our buildings and masonry. All of our outfit which was not needed for the pendulum observations at Singapore was sent directly back to New York by steamer.

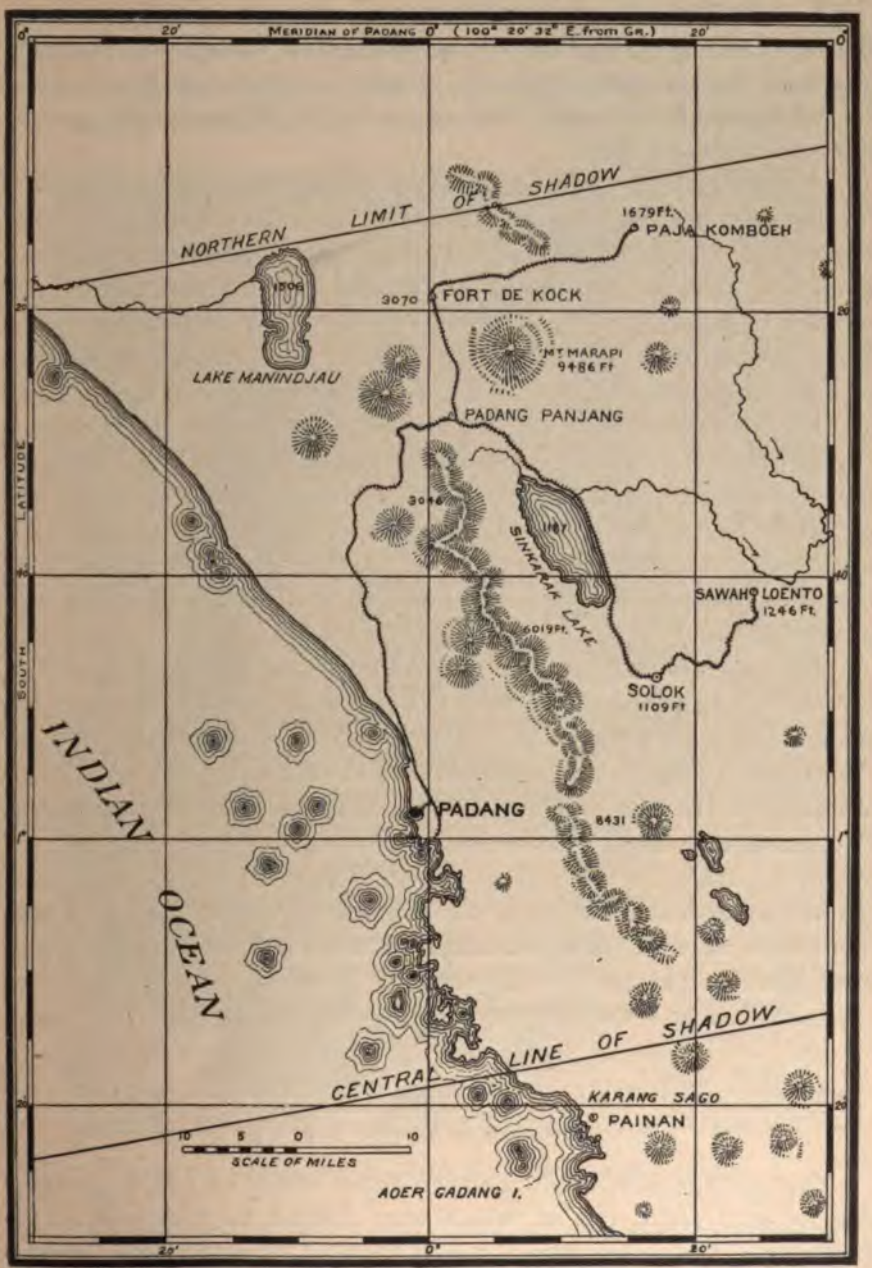


FIG. 7.—MAP SHOWING LOCATIONS OF ALL THE ECLIPSE EXPEDITIONS TO THE WEST COAST OF SUMATRA.

A collection of costumes, household utensils, and weapons, to illustrate the life and manners of the native Malays of Sumatra, was made by the writer, with the valuable assistance of Mr. Schilds, of Padang, for the Peabody Museum at Salem, Massachusetts, and is now on exhibition there.

On May 24th the party took passage on the "Koning Wilhelm II" for Batavia; here we made a close connection with the steamer "Van Riemsdijk," of the Royal Dutch Packet Line running to Singapore. From this port Mr. Smith and Mr. Matthes took the next connecting steamer to Japan, while Mr. Hosmer and the writer remained at Singapore to make the pendulum observations. Two stations were occupied on the ground floor of the European Hospital, one of these being at the exact spot used by the United States Government Party twenty years ago. We are grateful for assistance from the office of the Colonial Engineers, and we are especially indebted to Mr. R. Symonds Fry, in charge of the Time Service at Singapore, for the opportunity of using his transit in making the time observations. A record of the pendulum work is given in full in Mr. Hosmer's appended report.

All the remaining instruments of our equipment, with the exception of the three chronometers, were now packed and sent by steamer back to New York. Mr. Hosmer and the writer took the steamer "Bayern," of the German Mail, for Yokohama, Japan, stopping on the way at Hong Kong, Shanghai, Nagasaki, and Kobe. After fourteen days' sight-seeing in Japan, we embarked on the "America Maru," of the "Toyo Kisen Kaisha," Line, stayed half a day at Honolulu, and arrived at San Francisco August 1st. In a few more days we were back in Boston. Liberal reductions in rates had been given to the party on all steamer lines and railroads, and the greatest interest shown in our work by the officials whom we met.

Report of Photographic Work.

By HARRISON W. SMITH, A.B., S.B.

The photographic outfit included three lenses of 3-inch aperture and 135-inch focus, two of which were loaned by Professor E. C. Pickering. There was also a 3-inch lense of 40-inch focus, which, though not adjusted for photographic work, had been successfully used in Georgia in May, 1900, in photographing the faint elongations of the equatorial streamers. This lense was designed for use

both with ordinary plates and with isochromatic plates and a color screen. Of the first mentioned lenses, one was to be used for the corona, while two were for photographing regions of the sky east and west of the sun, in the search for intra-mercurial planets.

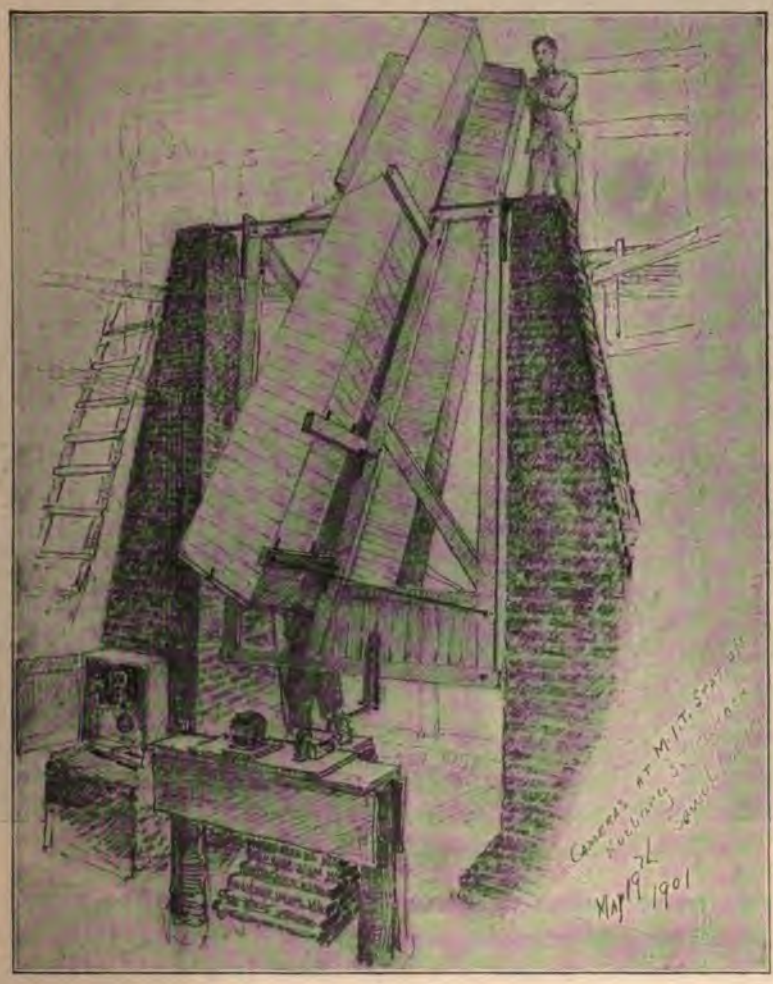


FIG. 8. — SKETCH SHOWING METHOD OF MOUNTING CAMERAS.

The cameras were long square boxes of pine sheathing, and were taken apart before leaving Boston and shipped in crates, this method of construction being found very light and especially satisfactory on account of the rigidity of the cameras after being mounted. All four

cameras were fastened to one framework, 6 feet wide by 8 feet high, which hung from a polar axis supported on brick piers, 11 feet in height. The fact that our station was only a few miles from the equator, and that the eclipse occurred a short time after noon, made this method of mounting very convenient. The polar axis was a steel shaft $1\frac{1}{4}$ inches in diameter, and the frame was supported by two brass straps passing over it. Thus the whole cluster of cameras — two on one side of the axis and two on the other — formed one

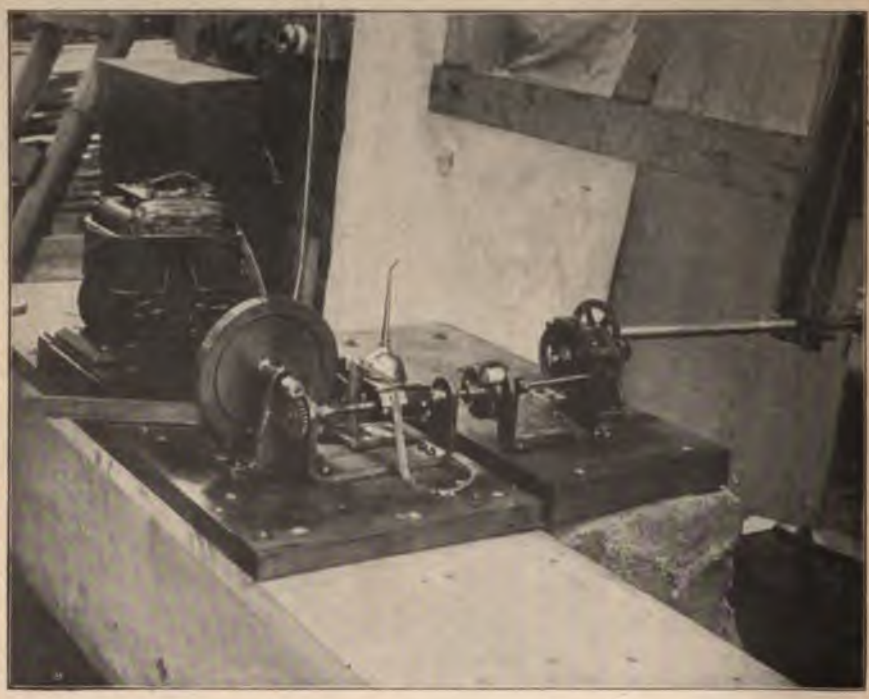
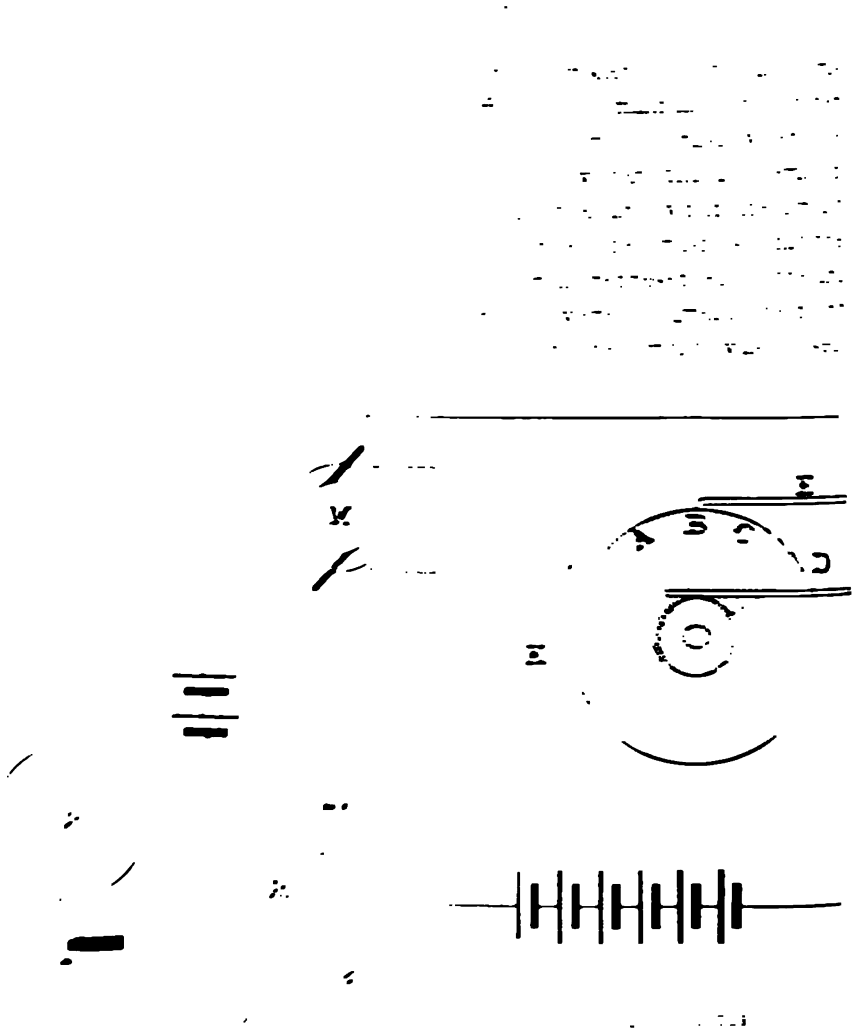


FIG. 9. — CONTROLLED MOTOR AND TANGENT SCREW.

rigid structure, so balanced as to swing freely through the necessary angle. Before the cameras were placed in position, they were focused on a dark window in a blue house at a distance of about two miles. A base line was measured and the distance determined by triangulation; the focus was then corrected for parallel rays, and finally the cameras were placed in position and the focus tested by obtaining trails from Arcturus, whose declination is very nearly the same as was that of the sun at the time of the eclipse. The trails showed that the focus was practically correct.

The driving of the cameras was accomplished by means of an electric motor, acting through a train of gear wheels on a tangent-screw. One end of the screw passed through a nut fixed at the end of the frame at a distance of 102 inches from the centre of the polar axis, while the other end was suitably supported on a brick pier. Figure 9 shows the arrangement of the motor, gearing, and tangent-screw before the cameras were placed in position. The motor was maintained at the proper speed by means of an exceedingly ingenious method of clock control, devised at the Harvard College Observatory by Professor E. C. Pickering and Mr. William P. Gerrish, which may be described as follows: A flexible coupling connects the motor to a comparatively heavy fly-wheel, which, in turn, is joined by a worm and gear to a shaft so designed that it will make exactly one revolution per second when the tangent-screw is being driven at the desired speed. This shaft, which may be seen at right angles to the motor shaft, is provided with a make-and-break contact (about halfway between the bearings), so arranged that a brush resting on a disk, composed half of brass and half of vulcanite, closes a circuit during one half of a revolution and opens it during the other half. Figure 10 is a diagram of the apparatus and the electrical connections, showing at *K* this contact disk, at *M* the motor, at *R* a relay, and at *P* the pendulum of the controlling clock, which beats half seconds. Attached to the end of the pendulum rod is a strip of platinum that, during each swing of the pendulum to the left of its middle position, cuts through a meniscus of mercury, thus alternately opening and closing a relay circuit at intervals of one half second. In the figure the meniscus of mercury is shown for clearness slightly below the platinum tip. This relay contact and the contact *K* are electrically connected in series with each other and with the motor, and are then joined to a storage battery of a size sufficient to furnish considerably more power than necessary to drive the motor at its proper speed.

Thus the motor is driven by a series of impulses, succeeding each other at intervals of one second, for the motor can only receive current when both the relay and the contact at *K* are closed. The figure represents the condition of things when the pendulum is just on the point of closing the circuit while the brush of the contact disk is on the point *B*; so that current will flow until the disk, revolving in the direction represented by the arrow, has brought the



[illegible] only.
[illegible] the clock
[illegible] after
[illegible] the average
[illegible] falls each
[illegible] any desired amount
[illegible] by a slight modification
[illegible] the motor be connected perma-
[illegible] resistance, inserted in series with
[illegible] to reduce the speed of the motor

somewhat below its normal rate ; the control device may then be used to short-circuit this resistance, thus producing a small acceleration each second and gaining the desired regulation with very small fluctuations in speed. A portable storage battery of six 5-ampere cells was found sufficient to drive the motor.

Through the courtesy of the ship's officers, the battery was charged on the steamer just before reaching Padang, and was maintained in perfect condition by means of a bichromate battery. This method of driving the cameras was found most satisfactory by the writer and gave no trouble whatever. The clicks of the relay and the hum of the motor, during the short intervals in each second when it is receiving current, produce a rhythmical sound, by which one very soon learns to judge accurately whether or not the motor is "in step" with the clock. For this reason, the method possesses a distinct advantage over many of the other forms of driving devices, in that, having once completed the adjustment, there is no possibility (aside from an exceedingly improbable change in the rate of the clock) that the apparatus will fail to work correctly without the operator becoming instantly aware of the fact.

Of the three cameras of 135-inch focus, the two used for photographing the sky near the sun were designed to take two 8 × 10 plates, each slightly tilted to improve the focus. As it was intended to give a very long exposure with these cameras, it was necessary to cut down the number of exposures for the other camera, which was intended to photograph the corona, it being considered unwise to attempt any manipulation on one camera while the others were exposing. Unfortunately, the long exposure was of no advantage, since the cloud was so dense on each side of the sun that scarcely any stars are to be found on the plates. Of the exposures with the third camera, the first, of one-half second for the prominences at second contact, and the last, of twenty seconds, were successful. The other negatives were badly fogged by the diffused light from the clouds, and are of no value. The two referred to are, however, good, clear negatives. The prominences, although not large, are interesting, and there is evidence of a very violent disturbance in the equatorial region on the easterly limb of the sun. This disturbance is also plainly visible on the negative of twenty seconds' exposure, and is accompanied by a marked crossing of the filaments, radiating from a point having a position angle of 60° to a distance of eight or nine minutes

of arc from the moon's limb. A particularly striking dark arch appears on the easterly limb over a prominence of which the position angle is 115°. The polar streamers extend nearly one-half diameter from the moon's limb and the equatorial streamers on the west fully one diameter. This negative was undoubtedly exposed at an opportune moment, when a slight opening in the clouds was passing over the sun, for it shows very little indication of fog. The negatives from the 40-inch camera are all fogged, and the writer scarcely hoped for anything better, since the appearance of the sky near the end of totality was very discouraging, a bright halo of light surrounding the sun on all sides. The more striking features of the corona and prominences are shown in the accompanying diagram, Figure 12.

A very weak Ortol developer was used, in which the plates were soaked from one and one half to two hours. Fortunately, ice was easily obtainable from Padang, for otherwise it would have been impossible to prolong the development to such an extent; in fact, it would have been difficult to accomplish anything, since the temperature of the water in the dark room was never below 80.5° F. The Seed double-coated plate was used for the corona, as it was found to have yielded excellent results at the eclipse of 1900. No more difficulty was experienced in manipulating these plates than the ordinary plates, and the writer is firmly convinced that the negative contains detail in the inner corona, which can be reproduced by careful shading of the negative during printing, that would have been lost by over-exposure in an ordinary single-coated plate. It is a pleasure to acknowledge the kindness of Mr. W. van der Valk in offering the use of a dark-room with excellent water.

For the purpose of keeping time, a special clock was arranged with the escapement wheel on the minute shaft, so that the minute hand read seconds and the hour hand minutes. The clock was started at the second contact at twelve, and the bell struck minutes and half minutes, thus indicating the lapse of the period of totality. Mr. A. M. D. van Kuylenburg attended to starting the clock and to giving signals. The writer is especially indebted to Mr. Ch. Logeman, engineer at the mines, for invaluable and skillful assistance in exposing the cameras.

In addition to the work already described, an attempt was made to photograph the shadow-bands by a method which, so far as the writer knows, has not previously been tried. Although the results

were not satisfactory, they were such as to make it appear that the method is worth another trial, especially since the bands were not sufficiently distinct to give the method a thorough test. In brief, it consists merely in exposing a sensitive plate directly to the bands themselves, rather than attempting, with a camera, to photograph them as they appear on a white screen. The exposing is done by means of a sort of large focal plane shutter. Three 8 × 10 plates

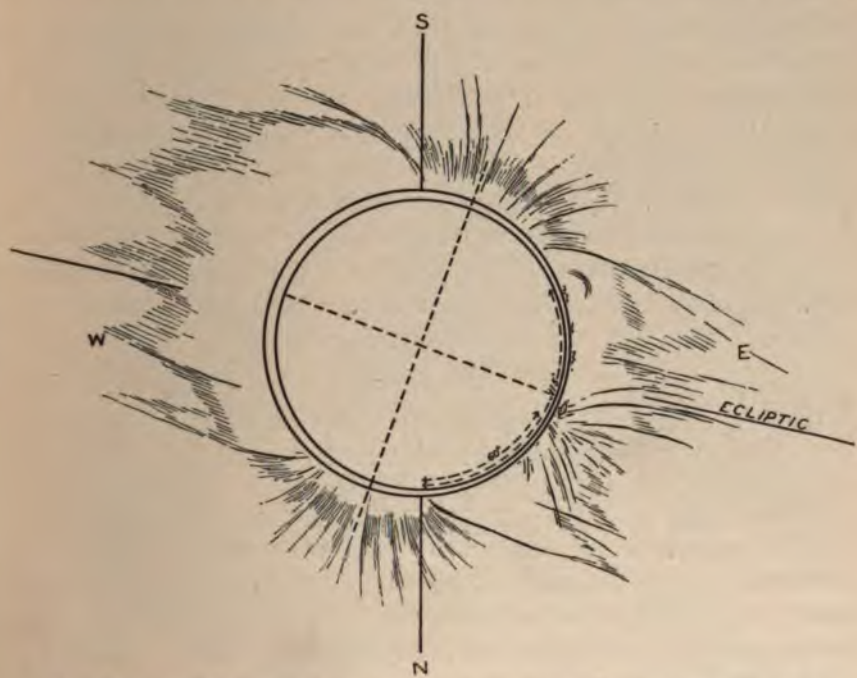


FIG. 12.—DIAGRAM SHOWING ANGULAR POSITIONS OF DISTURBANCES ON THE EASTERN LIMB OF THE SUN.

were placed in the bottom of a shallow box, giving an area 10 × 24 inches. Over this was a light-tight screen of two pieces of rubber gossamer, cemented together on the rubber side. The screen is attached at each end to a curtain roller, a narrow slot is cut across it at the proper point, and the operation of exposing consists in rapidly drawing this slot over the sensitive plate by means of rolling the screen up on one roller while it is being drawn off from the other. The boxes, for several were used, were laid flat on the ground, and were exposed under the direction of Mr. Matthes, who was familiar

with the appearance of the bands. The diffused light, however, was so great that it was hardly to be expected that the bands would appear upon the plates. In fact, the plates indicate over-exposure. As the exposures averaged about $\frac{1}{100}$ second, it is probable that $\frac{1}{200}$ to $\frac{1}{500}$ second, or, perhaps, $\frac{1}{1000}$ second, would be sufficient for plates of moderate speed. Plates of different speed were used, but as they all show over-exposure, it would probably be advisable in another attempt to err on the side of too short rather than too long exposure. It would be better, also, to substitute for the cloth a metallic screen that could be moved at a more uniform rate. It was found that a cloth screen, 12 inches or more wide, with a slot across nearly its entire width, did not run as smoothly as could be wished, while a metallic screen could be made to slide freely and would not be affected by having a slot of any width cut across it.

The apparatus was tested successfully on artificial shadow-bands before leaving Boston, and it is largely on this account that mention of it is made here, in the hope that it may be again tested at a later eclipse.

Report on the Changes in Declination of the Magnetic Needle during the Eclipse.

By GEORGE L. HOSMER.

The magnetometer was set up on the summit of a hill to the northeast of the eclipse station, in a hut built of wooden poles, bound together with rattan and thatched with grass. The tripod was set on wooden pegs, driven firmly into the ground. About 1,200 feet to the south a mark was set up, so that it could be seen with the telescope in the same position it would occupy during observations. The azimuth of the mark was found by triangulation from the true meridian established by the transit instrument. It was found to be 0° 53′ 17″ (S.W.). A brass lamp was placed at one side of the instrument, for illuminating the scale during totality. The magnet was suspended by new silk threads, which had been soaked in glycerine on May 16th. All iron or steel (except the watch) was removed to a distance of at least 50 feet. The watch kept the mean local time of the meridian of the transit pier. The vertical cross hair was pointed on the mark, and the magnet then suspended. Scale readings were taken every five minutes,

from 9*h.* 45*m.* A.M. to 2*h.* 15*m.* P.M. Additional readings halfway between were taken between 10*h.* 30*m.* and 2 P.M. Temperatures were read every ten minutes. At the close of the observations, the pointing on the mark was examined and found to be the same as at

FIG. 13. — MAGNETOMETER SHELTER.

the beginning. The scale reading of the axis as found from two observations on May 18th was 40.8*d.*

The value of one division of the scale is 1′.76. From a survey, the magnetic station was found to be 19″.0 north and 10″.2 east of the transit pier. The elevation of the station is 1,752 feet. Increasing scale readings correspond to increasing azimuth of magnet (in direction S W N E).

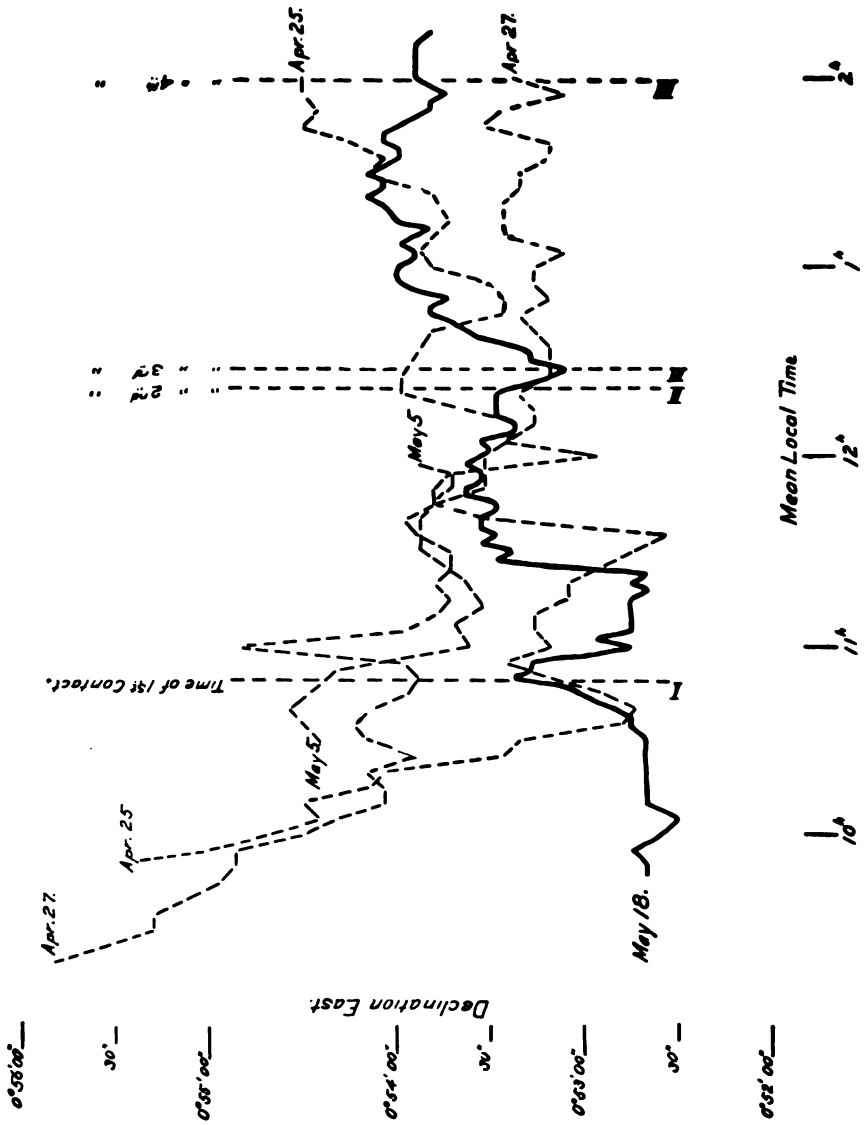


FIG. 14.—CURVES SHOWING CHANGES IN DECLINATION OF MAGNETIC NEEDLES AT SAWAH LOENTO, ON APRIL 25, 27, MAY 5, AND MAY 18, 1901.

TABLE OF SCALE READINGS. SAWAH LOENTO, MAY 18, 1901.

M. L. T.	Temperature.	Scale. L.	Scale. R.	Mean.
9 45		....	....	....
.....		37.0	43.9	40 45
50		37.2	43.7	40.45
55		38 2	42.8	40.5
10 00		38 9	41.9	40.4
	25.9°			
05		39.3	41.4	40.35
10		39 7	41.2	40 45
15		40.0	40.9	40.45
	26.0°			
20		40.2	40.7	40.45
25		40 2	40.7	40 45
30		39.7	41 2	40.45
	26 2°	39.9	41.0	40.45
35		40 0	41.0	40 5
		40.1	40.9	40 5
40		40 2	40 9	40 55
		40.3	40 9	40 6
45		40.4	40 9	40.65
		40.5	40.9	40.7
50		39.9	41.8	40.85
	26 5°	40.0	41.6	40.8
55		40.1	41 5	40.8
11 00		40.1	41.1	40.6
		40.1	40 9	40.5
11 00		40.1	40.9	40.5
	26.6°	40 3	40.9	40.6
05		40 3	40.7	40.5
		40 3	40 7	40.5
10		40 4	40 6	40.5
		39 2	41.8	40.5
15		39.4	41.6	40.5
	26.8°	39.6	41 3	40.45
20		39 9	41.1	40.5
		39.9	41.0	40.45
25		40.2	41.1	40.65
	27.0°	40.4	41 4	40.9
30		40 5	41.2	40.85
		40.7	41.2	40.95
35		40.7	41.5	40.9
	27.0°	40 8	41.1	40.95
40		40 9	41 0	40.95
		40.4	41.4	40.9
45		40 5	41 3	40.9
		40.7	41.3	41.0
50		40.8	41.2	41 0
	27.0°	40 8	41.1	40.95
11 55		40 8	41.1	40 95
	26.8°	40 3	41.7	41.0
12 00		40.4	41.5	40.95
		40.5	41.3	40.9
05		40 6	41.3	40 95
		40.6	41.1	40.85
10		40 6	41.1	40.85
	26 6°	39.8	42.0	40.9
15		40.0	41.8	40.9

TABLE OF SCALE READINGS. SAWAH LOENTO, MAY 18, 1901. — *Concluded.*

M. L. T.	Temperature.	Scale. L.	Scale. R.	Mean.
	26.4°	40.1	41.7	40.9
20		40.2	41.6	40.9
		40.3	41.4	40.85
25		40.3	41.2	40.75
	26.0°	40.4	41.0	40.7
30				
	25.9°	37.4	44.2	40.8
35		37.6	44.0	40.8
40		38.2	43.5	40.85
		38.8	43.1	40.95
45		39.2	42.8	41.0
		39.7	42.4	41.05
12 50		39.9	42.3	41.1
	25.5°	40.1	42.1	41.1
55		40.2	41.9	41.05
		40.4	41.9	41.15
1 00		40.6	41.8	41.2
	25.6°	40.7	41.7	41.2
05		40.9	41.5	41.2
		40.9	41.4	41.15
10	25.6°	40.9	41.4	41.15
		41.0	41.4	41.2
15		41.0	41.3	41.15
20	25.6°	41.0	41.2	41.1
		40.2	42.2	41.2
25		40.6	41.9	41.25
		40.8	41.8	41.3
30		40.9	41.6	41.25
		40.9	41.6	41.25
35		41.0	41.6	41.3
		41.0	41.5	41.25
40		41.0	41.4	41.2
		39.0	43.4	41.2
45	26.1°	39.5	43.0	41.25
		39.9	42.6	41.25
50		40.1	42.3	41.2
		40.2	42.1	41.15
55		40.3	41.9	41.1
		40.4	41.8	41.1
2 00		40.5	41.6	41.05
05		40.7	41.5	41.1
10		40.8	41.5	41.15
15		40.9	41.4	41.15
		41.0	41.3	41.15
		41.0	41.2	41.1

In the accompanying plot, Figure 14, the heavy line is the curve of May 18th. The dotted lines are curves obtained on three different days before May 18th. These observations were made at a different station, so that they are not strictly comparable with the curve obtained on the day of the eclipse; but they all show that ordinarily

the declination is decreasing during that part of the day, while on May 18th the declination increased.

In addition to the above, the following magnetic observations were made at Sawah Loento:

April 27, 1901.	Decl. = 0° 56.4′ E. of N.
May 4, 1901.	Dip. = 20° 33.4′.

Pendulum Observations Made in Connection with the Massachusetts Institute of Technology Eclipse Expedition to Sumatra.

By GEORGE L. HOSMER.

The program of gravity observations made in connection with the eclipse expedition is as follows:

The three pendulums of "Apparatus B" were swung at the office of the United States Coast and Geodetic Survey at Washington, between February 5th and February 7th, 1901. At Sawah Loento, Sumatra, during the time occupied in preparing for the eclipse, a set of observations was made between May 6th and May 8th. The party sailed from Padang on May 29th, and went directly to Singapore. At this point two sets of swings were made — the first between June 7th and June 10th; the second between June 12th and June 14th. The second set was made on the same spot occupied by the "Transit of Venus Party" in 1882; the first was made under practically the same conditions. After returning to the United States, the pendulums were again swung at the Coast and Geodetic Survey Office, between October 8th and October 10th.

During the February observations at Washington, chronometer No. 1823 Negus was used for observing the coincidences. The time was determined by transits of about eight stars, recorded on a chronograph. On account of a leakage of the receiver during the last swing, due to improper sealing of the joint, this set is incomplete. There was so little time remaining before the date of sailing that a complete set could not be obtained.

At Sawah Loento, Sumatra, the pendulum apparatus, transit, and chronograph were all placed in a small bamboo hut. The pendulum case was mounted on a solid brick pier, 75 cm. square, 30 cm. above the surface and 75 cm. below the surface. The flash apparatus was set on a small brick pier of convenient height. Time was determined

by star transits, observed by a 2½-inch meridian telescope, mounted on a brick pier. The observations were recorded by chronograph. The sets consisted of eight or more stars, chosen so as to determine the instrumental errors. The chronometer, Bond No. 541, was placed

FIG. 15.—TRANSIT AND CHRONOGRAPH AT SAWAH LOENTO STATION.

on a pier, and was not disturbed during the series. At this station there was no leakage, and the swings were satisfactory. The approximate position of the station is: latitude, 0° 41′ 40″ south; longitude, 100° 46′ 40″ east. The altitude above sea level = 1,246 feet. The sketch, Figure 4, shows the pendulum station and vicinity.

At Singapore the apparatus was set up in the laboratory of the

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General Hospital. This room has a solid tiled floor. The receiver was placed near a corner of the room, so as to be near the supporting columns. The pier built by the Coast Survey party in 1882 was found to be in good condition, but it was not necessary to use it.

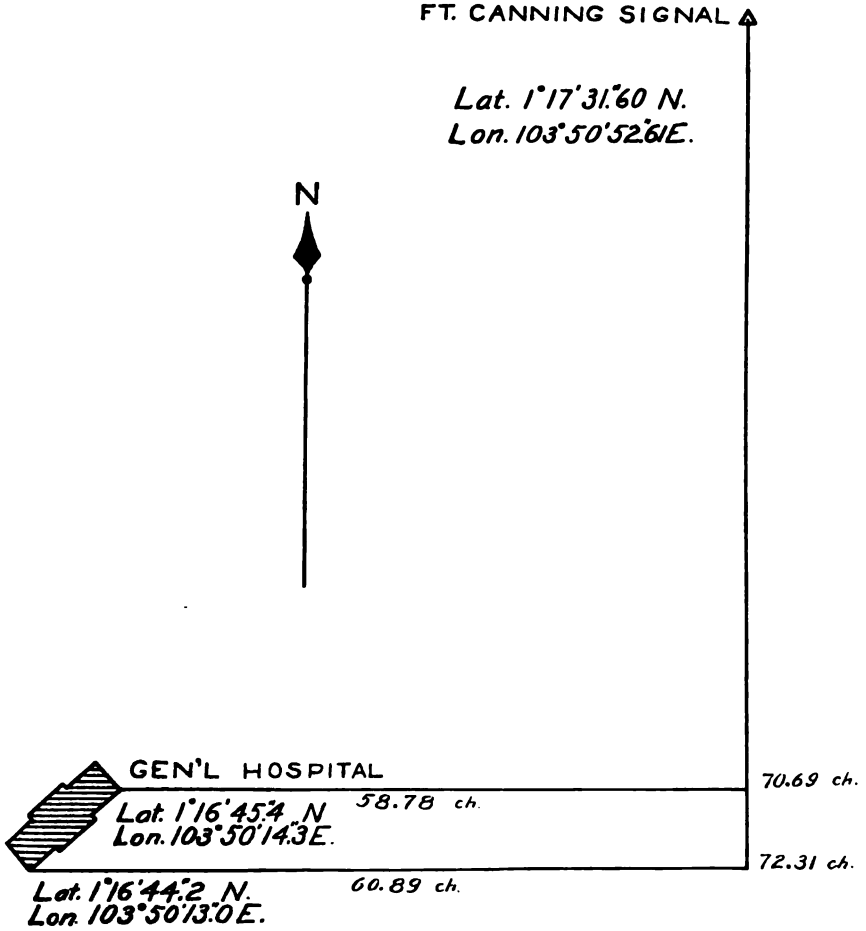

FIG. 16.—DIAGRAM SHOWING LOCATION OF GENERAL HOSPITAL BUILDING AT SINGAPORE. PENDULUM STATIONS IN EAST AND SOUTH CORNERS OF HOSPITAL BUILDING.

It was found that an excellent time service was carried on at the observatory. Mr. R. S. Frye, the observer, kindly offered to make special observations for our work. The rate of No. 541 was determined by comparison with the standard sidereal clock (Kullberg 5364), two

mean time chronometers being used for making the comparisons. Sidereal chronometer, Bliss and Creighton No. 1307 was also carried, and compared through the mean time chronometers. Care was taken that chronometer No. 541 should not be disturbed during the set. After this first set was completed, it was discovered that the laboratory in 1882 was at the other end of the building, in a similar room. Although the difference would be very slight, still it was decided best to occupy the very same spot used by the "Transit of Venus Party," and thus have two sets of swings as a check. The first set was made in the east corner and the second set in the south corner of the building. The following information was furnished by the office of the Colonial Engineers. The position of the flagstaff at Fort Canning is as follows:

$$\begin{cases} \text{Lat. } 1^\circ\ 17'\ 31.6''\ \text{N.} \\ \text{Long. } 103^\circ\ 50'\ 52.61''\ \text{E.} \end{cases}$$

(From Trig. Chart, 1893.)

The accompanying diagram, Figure 16, shows the position of the Hospital building with reference to the flagstaff, as furnished by the Colonial Engineers' Office.

During the October observations at Washington, chronometer, Blunt and Nichols No. 353 was used (loaned by United States Geological Survey). No chronograph was available, so eye and ear observations had to be made. For this reason it was necessary to move the chronometer from the pendulum room to the observatory. The swings of this set were satisfactory so far as the pendulum apparatus was concerned.

The apparatus used was the set of half-second "invariable" pendulums, belonging to the United States Coast Survey, known as "Apparatus B." It consists of three half-second pendulums, marked B4, B5 and B6. These are swung in an air-tight case, and are supported on a knife edge fastened to the case. An agate plane is set into each pendulum at the point of support, and rests on the knife edge. A manometer is placed within the case for measuring the pressure of the air. A thermometer is attached to a special pendulum, called a "dummy" or "temperature pendulum," which is hung inside the case, beside the swinging pendulum. There is a metallic contact between the thermometer bulb and the "dummy," made by means of filings of the alloy of which the pendulums are made. This

is done in order to obtain, as nearly as may be, the temperature of the swinging pendulum. A second thermometer is suspended within the case, in order to check the first thermometer.

The "flash apparatus" is a mechanism for throwing a flash of light on to two small mirrors — one on the pendulum, the other beside it on the case. A small lamp at one side throws light on to a mirror within the apparatus. This mirror sends the beam of light through a narrow slit to the mirrors in the pendulum case. From these two mirrors it is reflected to the observing telescope at the top of the apparatus. Behind the mirror inside the apparatus is an electro-magnet, the armature of which is attached to a slide, which moves in front of the slit, so that in a certain position the slit is open for an instant. The "flash apparatus" and the chronometer are both included in an electric circuit. The chronometer breaks the circuit at the end of every second (or every two seconds). When the circuit is broken, the movement of the armature causes the slit to be opened for an instant, and a flash of light is sent to the pendulum and reflected by the two mirrors. The flash on the fixed mirror is always in the same position, while that on the pendulum changes continually, depending upon the position of the pendulum at the end of the second. In a certain position of the pendulum the flashes will coincide. When the pendulum moves away from this position and returns to it again, it loses just one oscillation, compared with the chronometer beats. From this interval the period, in terms of the seconds of the chronometer, can be found. In connection with this observation it is necessary to know (1) the arc of oscillation at the beginning and end of the swing; (2) the pressure of the air in the receiver; (3) the temperature of the pendulum; (4) the movement of the support; and (5) the rate of the chronometer on true sidereal time.

In this series of observations the same plan was followed out as has been used by the Coast and Geodetic Survey, viz., the swings were begun in the evening immediately after time observations, and the three pendulums swung in the direct and reversed positions, each swing lasting about eight hours, so that the last one ended immediately after time observations two nights later. In case star observations could not be obtained at the time, the swings were continued until they could be obtained.

The uncorrected period is found by the relation:

$$P = \frac{s}{2s - 1}$$

where s is the number of seconds in one interval between successive coincidences of the flash. A sufficient number of coincidences is observed to enable the observer to estimate the total number of coincidences that have taken place during the eight hours. This period is then corrected as follows:—

(1) Reduced to infinitely small arc.
(2) " " temperature 15° C.
(3) " " pressure 60^{mm} at 0° C.
(4) " " rigid support.
(5) " " true sidereal time.

The formulæ for these corrections are:

$$(1)\ \text{Arc corr.} = -\frac{PM}{32} \cdot \frac{\sin(\phi + \phi')\sin(\phi - \phi')}{\log\sin\phi - \log\sin\phi'}.$$

M = modulus of common log. system.
ϕ and ϕ' = the initial and final arcs.
P = the period.

(2) Temp. corr. $= + .000\,008\,37\ P(15° - T°)$.
$T°$ = observed temperature.

(3) Pressure corr. $= + .000\,000\,101 \left[60 - \frac{Pr.}{1 + .00367\ T°}\right]$.

(4) Flexure corr. $= - .000\,000\,65\ D$.
D = movement in microns.

(5) Rate corr. $= + .000\,011\,574\ R.\ P.$
R = daily rate on sidereal time; + if losing, — if gaining.

For computing g, we have:

$$g_o = \frac{P_w^2}{P_o^2}\, g_w,$$ where P_w is the period at Washington, P_o the observed period, and g_w the absolute value of g at Washington.

TABLE A. — CHRONOMETER RATES.

STATION.	INTERVAL.	CHRONOMETER (rate on sidereal time).		
		No. 1823	No. 541	No. 353
Washington	Feb. 5–7.	+ 4.^{s}80	.....	.....
Sawah Loento	May 6–8.	.....	+ 2^{s}.21	.....
Singapore	June 7–8.	.....	+ 4.87	.....
Singapore	June 9–10.	.....	+ 4.69	.....
Singapore	June 12–14.	.....	+ 4.50	.....
Washington	Oct. 8–10.	.....	.....	+ 0.^{s}27

FIG. 17. — SOUTH CORNER OF GENERAL HOSPITAL BUILDING, SINGAPORE.
Pendulums were swung in the corner near which the man is standing.

TABLE B. — SINGAPORE, STRAITS SETTLEMENTS, EASTERN CORNER OF BUILDING.

Swing.	Pendulum.	Position.	Knife edge.	Date. 1901.	Coincidence interval.	Total Arc. Initial.	Total Arc. Final.	Corrected temperature. C.	Pressure at 0° C.	Period Uncorrected.	Corrections. 7th Decimal Place. Arc.	Temperature.	Pressure.	Rate. No. 541.	Flexure.	Period Corrected.
									mm.							
1	B4	D	I	June 7	183.58	58′	17′	28.60°	55.2	.5013655	— 8	— 570	+ 5	+ 282	— 12	.5013352
2	B4	R	I	June 7–8	183.64	58′	16′	28.60°	52.7	3788	— 8	— 570	+ 7	+ 282	— 12	3487
3	B5	D	I	June 8	196.14	52′	11′	28.85°	56.5	2650	— 5	— 581	+ 3	+ 282	— 12	2337
4	B5	R	I	June 9	196.49	52′	15′	28.15°	49.9	2628	— 7	— 551	+ 10	+ 272	— 12	2340
5	B6	D	I	June 9	208.79	52′	16′	28.25°	56.0	2002	— 7	— 555	+ 4	+ 272	— 12	1704
6	B6	R	I	June 9–10	209.80	55′	17′	27.85°	54.3	1825	— 8	— 538	+ 6	+ 272	— 12	1545
														Mean		.5012461

TABLE B. — Singapore, Straits Settlements, South Corner of Building.

Swing.	Pendulum.	Position.	Knife edge.	Date. 1901.	Coincidence interval.	Total Arc. Initial.	Total Arc. Final.	Corrected temperature, C.	Pressure at 0° C.	Period Uncorrected.	Corrections. 7th Decimal Place. Arc.	Temperature.	Pressure.	Rate. No. 541.	Flexure.	Period Corrected.
									mm.							
1	B4	D	I	June 12–13	184.38	52′	17′	26.95°	55.5	.5013459	— 8	— 501	+ 4	+ 261	— 12	.5013203
2	B4	R	I	June 13	184.23	51′	16′	26.95°	55.3	3607	— 7	— 501	+ 5	+ 261	— 12	3353
3	B5	D	I	June 13	196.69	52′	16′	27.30°	52.9	2870	— 7	— 515	+ 7	+ 261	— 12	2604
4	B5	R	I	June 13–14	197.07	53′	17′	26.85°	53.0	2591	— 7	— 496	+ 7	+ 261	— 12	2344
5	B6	D	I	June 14	209.90	52′	16′	26.70°	57.3	1939	— 7	— 490	+ 3	+ 261	— 12	1694
6	B6	R	I	June 14	209.80	53′	14′	27.20°	56.2	1832	— 7	— 511	+ 4	+ 261	— 12	1567
														Mean		.5012461

STAR OBSERVATIONS FOR TIME AT SAWAH LOENTO, SUMATRA, MAY 6, 1901.

Station, Sawah Loento. Date, May 6, 1901. Observer, G. L. H. Chronometer, Bond 541.

41 L. Min.		ι Leonis.		P³ Leonis.		δ Crateris.		τ Leonis.		ξ Hydræ.		υ Leonis.		ζ Urs. Maj.	
Clamp E		E		E		E		W		W		W		W	
50.0		27.0	7.0	55.5		27.5	8.0	42.0	40.5	.115		18.5	18.0	13.0	24.0
18.0															
	.320	23.0	11.0	15.0		28.0	7.0	30.5	34.0	.065		12.0	24.0	21.0	16.5
+32.0	.405														
		50.0	18.0	40.5		55.5	15.0	11.5	6.5	2) 180		30.5	42.0	34.0	40.5
.01	2) 725			.01				.01	.01						
										—.090					
+.320	+.362			.405				—.115	—.065						
		h_e = +.362								δ_{α} = —.090					
10 51	37.18	57	40.00	11 15	28.60	28	00.00	36	27.55	41	41.07	45	29.63	54	12.92
	41.32		44.00		32.63		04.00		31.68		45.80		33.80		19.15
	45.95		48.30		36.72		08.28		35.75		50.60		37.80		25.35
	54.86		56.60		44.85		16.65		44.12	42	00.58		46.24		37.85
	59.44	58	00.94		49.05		21.08		48.42		05.52		50.46		44.40
52	03.65		04.86		52.75		24.96		52.72		10.60		54.77		51.00
	08.35		09.40		57.30		29.45		56.70		15.20		58.65		56.72
	13.10		13.70	16	01.60		33.70	37	00.80		20.00	46	02.78	55	03.10
	22.16		22.07		09.67		42.30		08.85		29.32		10.85		15.00
	26.53		26.43		13.85		46.70		13.28		34.44		15.15		21.35
	31.09		30.40		18.00		50.85		17.05		39.04		19.05		27.40
52	03.96	58	05.15	15	53.18	28	25.27	36	52.45	42	10.20	45	54.47	54	50.38
ε	—.02		—.02		—.02		—.02		—.02		—.02		—.02		—.02
3b	+.36		+.36		+.36		+.36		—.09		—.09		—.09		—.08
τ	—.06		—.05		—.03		.00		+.01		+.02		+.03		+.04
t 10 52	04.24	58	05.44	11 15	53.49	28	25.61	36	52.85	42	10.11	45	54.39	54	50.32
α 10 38	04.42	44	05.62	01	53.69	14	26.00	22	53.32	28	10.72	31	55.39	40	52.22
α-t_1 13	59.82	13	59.82	13	59.80	13	59.61	13	59.03	13	59.39	13	59.00	13	58.10

COMPUTATION OF CHRONOMETER CORRECTION FROM STAR OBSERVATIONS AT SAWAH LOENTO, MAY 6, 1901.

	Star.	Pos.	$\alpha - t_1$	C	A	Cc	Aa	ΔT $\alpha - t_1$ -Cc-Aa.	v	
	41 L. Min.	E	59.82	− 1.09	− .45	− .34	− .19	−59.29	.09	
	l Leonis	E	59.82	− 1.02	− .21	− .33	− .09	.40	.02	
	P³ Leonis	E	59.80	− 1.00	− .05	− .33	− .02	.45	.07	$\Delta T = -13^m\ 59^s.37$
	δ Crateris	E	59.61	− 1.03	+ .24	− .33	+ .10	.38	.00	at $11^h\ 30^m$
	τ Leonis	W	59.03	1.00	− .07	+ .33	+ .05	.41	.05	
	υ Leonis	W	59.00	1.00	− .00	+ .33	.00	.33	.03	
	χ Urs. Maj. . . .	W	58.10	1.49	− 1.13	+ .50	+ .76	.36	.00	
	ξ Hydræ	W	59.39	1.16	+ .59	+ .34	− .40	.33	.03	
			$\alpha - t_1$	C	A	Cc	$\alpha - t_1$-Cc	Aa	$\alpha - t_1$-Cc -Aa	c = + .20
1st approx.	Mean of N stars,	E	59.81	− 1.04	− .24	− .21	59.60	− .10	−59.50	$a_e = +.417$
	Mean of S stars,	E	59.61	− 1.03	+ .24	− .21	59.40	+ .10	−59.50	
	Mean of N stars,	W	58.71	+ 1.16	− .40	+ .23	58.94	+ .27	−59.21	$a_w = -.687$
	Mean of S stars,	W	59.39	+ 1.16	+ .59	+ .23	59.62	− .40	−59.21	
2d approx.	Mean of N stars,	E				− .34	59.47	− .10	−59.37	c = + .330
	Mean of S stars,	E				− .34	59.27	+ .10	−59.37	$a_e = +.417$
	Mean of N stars,	W				+ .38	59.09	+ .27	−59.36	$a_w = -.667$
	Mean of S stars,	W				+ .38	59.77	− .40	−59.37	

Example of Pendulum Observations.

Washington, D.C. February 6, 1901. Pendulum B5 reversed. Knife edge I.

	Coincidences.	Pressure.	Temperature.	Arc.
		mm.		mm.
U	9 — 24 — 38	37.5	9.2° C.	4.5
D	30 — 40	37.5		
		75.0		
U	37 — 05			
D	43 — 05			
	.....			
	.....			
	.....		(February 7 A.M.)	
	.....			
		mm.		mm.
D	16 — 59 — 28	38.0	8.4°	1.3
U	17 — 06 — 33	38.0		
		76.0		
D	12 — 06			
U	19 — 06			
D	24 — 37			

Total time interval = 27,703.6s.
Number coincidences = 37.
Time in one double interval = 748.75.
Time in one interval = 374.38.
Period = .5006754.

Latitude Observations.

Sawah Loento, Sumatra.

Date.	Pair. Gr. 10 Yr. Cat.	Latitude.
May 14, 1901.	1712 / 1732	— 0° 41′ 41.42″
May 14, 1901.	1784 / 1791	— 0° 41′ 37.37″
May 14, 1901.	1884 / 1891	— 0° 41′ 41.27″
		Mean = — 0° 41′ 40.02″

A STUDY OF CERTAIN SHADES AND GLOBES FOR ELECTRIC LIGHTS AS USED IN INTERIOR ILLUMINATION.

BY WILLIAM LINCOLN SMITH, S.B.

PART II.

[*Continued from Vol. XIII, page 176.*]

A. GENERAL CONSIDERATIONS.

IN the first part of this paper[1] were given distribution curves of incandescent lamps fitted with various types of shades or globes, and the efficiency of the several combinations was determined by finding the Mean Spherical Candle-power and the Energy consumption in the usual manner. The Mean Spherical Candle-power is, in my opinion, the quantity by which in the last resort one must compare relative efficiencies, unless one is willing to lose himself in a maze of cross purposes and entangling specialties, among which it is exceedingly difficult to find any other simple and satisfactory basis of comparison.

Here as elsewhere, however, one must not fall into the error of making efficiency the only criterion.

There is, first, the broad and complex matter of *color effect* to be considered, since it by no means follows that because a particular effect is satisfactory in one case, it will be even bearable in another, where the same general arrangement holds, but the color scheme and character of decoration is widely different. For examination along this line we must call in the aid of the Spectro-photometer, and the corresponding section of this work is reserved for part three of this paper, the preparation of which is at present in progress.

The second point to be considered is that of *distribution of light over surfaces to be illuminated.* It is only in very rare cases that it

[1] TECHNOLOGY QUARTERLY, Vol. XIII, page 176. September, 1900.

is advisable to use modern light sources, as Welsbach mantles, acetylene gas, incandescent or arc lamps, unaccompanied by some form of diffusing shade or globe, for most frequently the source will come somewhat within the line of vision. In this case the intrinsic brilliancy must be cut down, — all the newer light sources agreeing in this: that the value of the candle-power emitted per unit of area of light-giving surface is very high. Thus the open arc may give over 25,000 C. P. to the square inch, the incandescent lamp may range from 100 to 200, acetylene gas ranges from 75 to 125, while the Welsbach mantle will vary from 20 to 25. Now, of the older light sources, the flat flame of gas gives from 4 to 8; the oil lamp, from 3 to 8, both varying widely, however; and the candle is lower still. It is safe to say that the intrinsic brilliancy should never rise above five candle-power per square inch, and personally I prefer to keep it rather lower if possible.

Thus it will be seen readily that the use of some form of diffusing shade is necessary in the great majority of cases, in order that the light may appear to radiate from a much larger surface than is the case with the bare lamp, and thus the intrinsic brilliancy be properly reduced. But the shade ought to do more than this, it should aid us from the point of view of *illumination* as distinct from *lighting*, and it is just this distinction which the great majority of persons fail to take into account. For instance, let us consider a draughting room. Suppose we hang lights on pendant cords over each drawing table; the illumination of the boards will be strong and bright, yet the room may be very badly lighted. For if the lamps are fitted with conical green paper or tin shades the whole upper part of the room will be in gloom and the worker's eyes strained as he raises them from his work and then drops them again; while if the lights are bare the conditions may be as bad, if not worse; since, if the lamps are high, it will be difficult to get light enough at the proper angle on the board, and, if low, they may easily come within the range of vision. In either case the workman will find that on raising his eyes from his work they are strained, just as when the shades were used. In the first case the iris dilated to accommodate itself to the gloom of the room as compared to the board, in the second case it contracted to accommodate itself to the presence of the small, bright light sources; so that the alternate opening and closing will finally result in serious strain, and may do irreparable

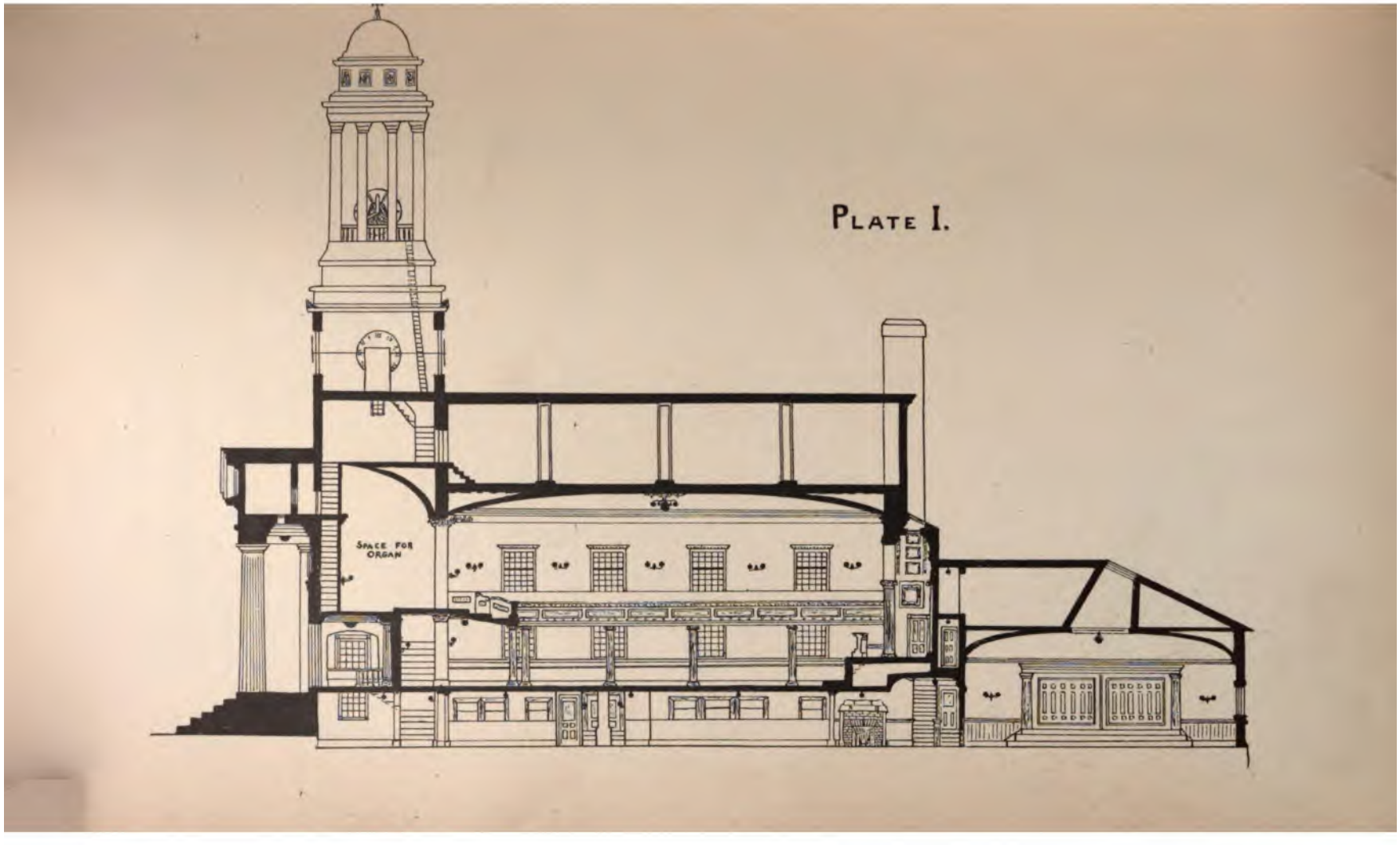

PLATE I.

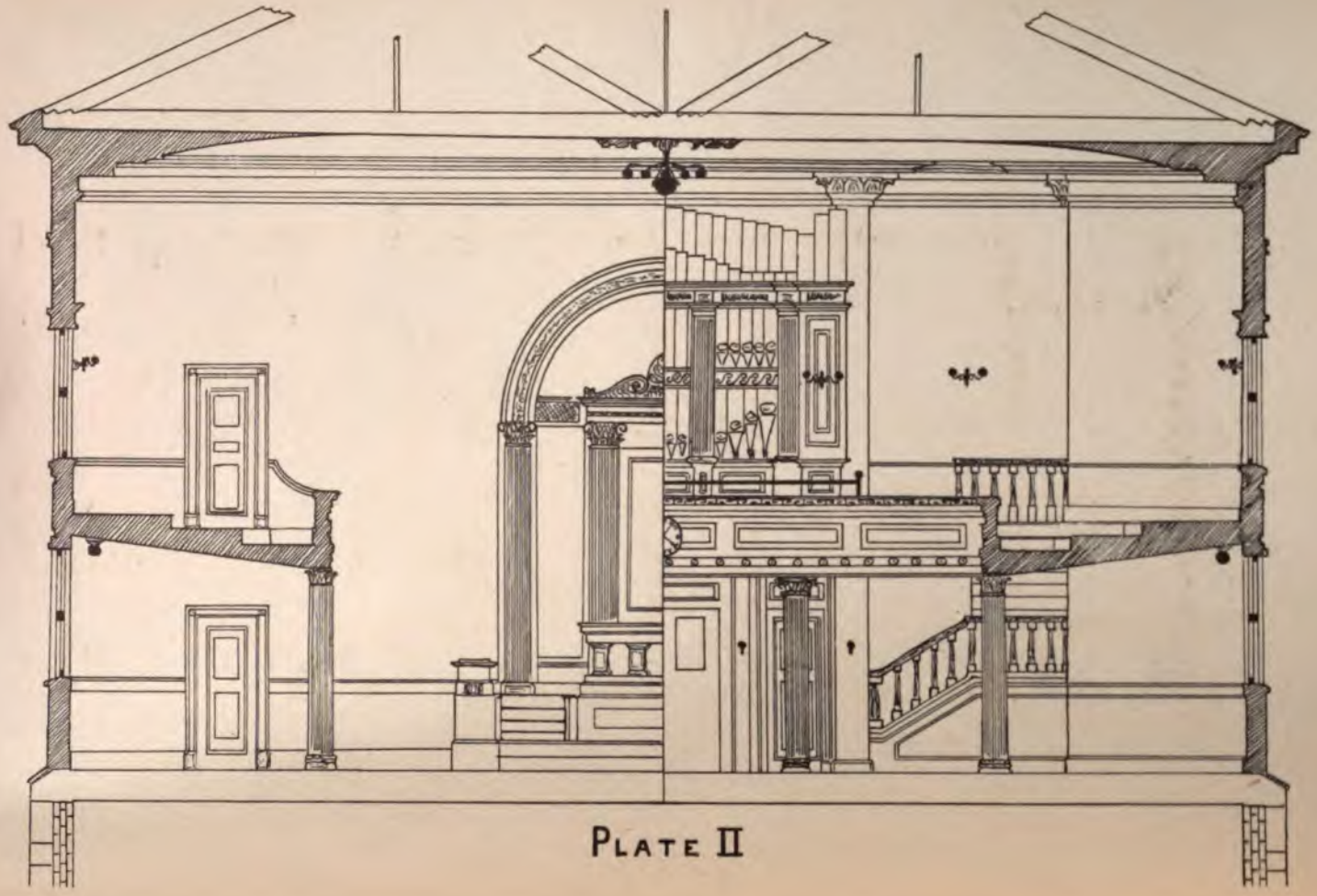

PLATE II

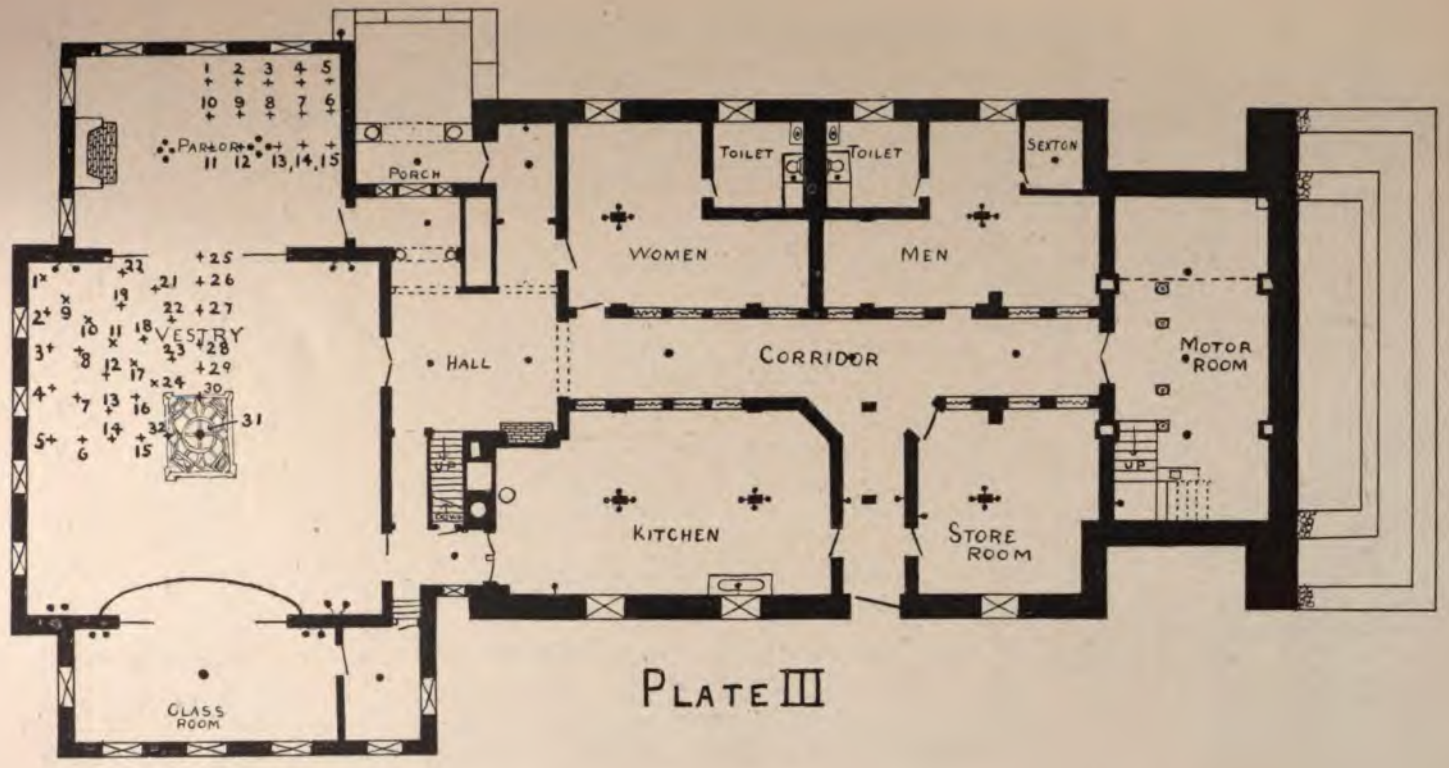
PARLOR
PORCH
VESTRY
HALL
TOILET
TOILET
SEXTON
WOMEN
MEN
CORRIDOR
MOTOR ROOM
KITCHEN
STORE ROOM
GLASS ROOM

PLATE III

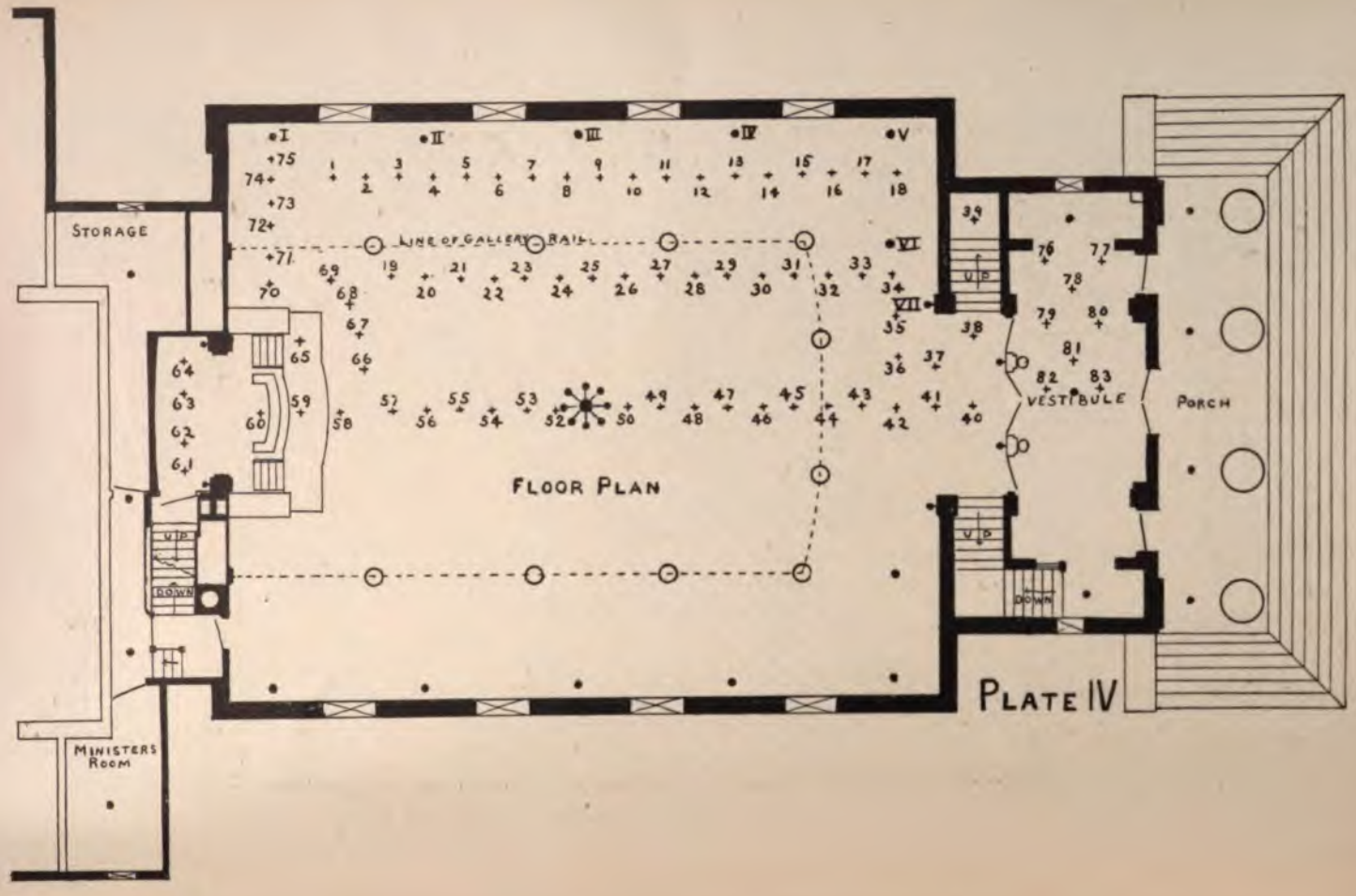
STORAGE
MINISTERS ROOM
LINE OF GALLERY RAIL
FLOOR PLAN
VESTIBULE
PORCH
UP
DOWN

PLATE IV

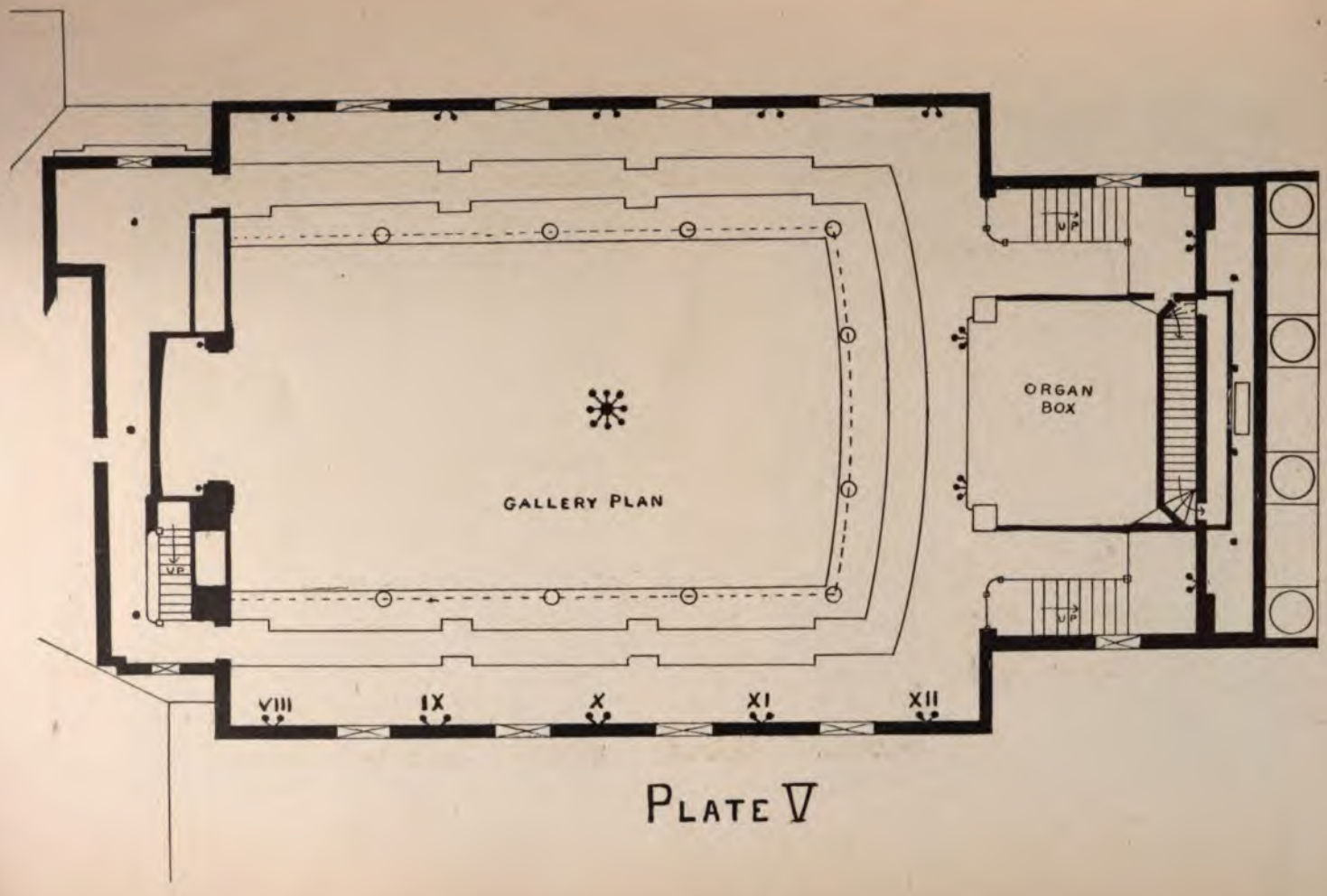

PLATE V

East End. Electric Light.

East End. Daylight.

Plate VI.

West End. Electric Light.

West End. Daylight.
Windows on the right hand were the brightest.

Plate VII.

damage. We get, in other words, good illumination but very bad lighting. Now suppose this room to be lighted by concealed lamps of high power, their light being thrown on to a white diffusing surface, as a slightly arched ceiling and whitened walls, the room will be excellently lighted, but the working illumination will be bad, for we shall have approached so nearly to complete diffusion and uniformity that the result will again be strain and damage to the eye, resulting in this case from the total absence of shadow and the consequent inability of the eye to readily locate a point on the paper or to judge of distance; the strain now falling upon the focusing apparatus instead of, as previously, upon the muscles controlling the iris.

Between these two extreme cases will be found a happy mean, which may be more or less closely approximated in a variety of ways. In the room considered above, it would be found in providing a moderate general illumination by the hidden lights, and fitting each table with a small, thoroughly shaded lamp, flexibly supported, so that its rays could be directed at any desired angle upon any desired portion of the work.

Such a lay-out, however, would prove decidedly expensive, and an approximation to the result might be made by the use of larger lamps raised high and fitted with globes which would cut down the intrinsic brilliancy properly, and at the same time direct the light downward, so as to give sufficient illumination.

Accordingly, it is of great importance for one to be able to determine beforehand just what a given arrangement is going to give in the way of illuminating effects. In some cases one can say offhand that the results will be thoroughly bad. Thus, if a globe like No. 15, Part I of this paper[1] (a globe with the top half opal and the lower half clear glass cut with a many-rayed star), be used, the result will be unsatisfactory for many purposes, because the globe will produce very marked striations on a surface below.

Again, take the case of the turnip type of incandescent lamp, with the upper half silvered. If the bottom half is clear glass, the light downward will be very intense, but the illuminated surfaces will be crossed and cut up by caustics and striations of great prominence. If, on the other hand, the lower half be frosted, the light will be much reduced (which does no great harm, because almost everyone just now is carried away by the delusion that the more powerful the illumina-

[1] *Loc. cit.*

tion the better he can see, than which there is no greater error), but the illuminated surface will show no trace of striations and the result will be good.

In the cases of many other globes and shades, indeed in the great majority, it is very difficult to tell just what will be the effect, even if the distribution in the mean vertical plane (found by spinning the combination) is known. Globes of the same pattern frequently vary widely among themselves, and the distribution of a given globe varies with the azimuth, so that it is altogether too laborious to attempt a calculation, with the probability in view that it will prove fallacious in the end.

It is herein, in my opinion, that one of the greatest advantages of the Holophane glass is to be found. As Part I of this paper shows, the efficiency of the globes is excellent, the light can be thrown practically in any desired direction, and the diffusing action is practically perfect. I think that this Part will show that they also excel in the uniformity existing among individual globes of the same type, and in the precision with which they allow the determination beforehand of the results to be attained, — such precision, of course, being an important indication of scientifically correct design and careful manufacture.

B. Method of Determining the Illumination on a Surface.

Given a lamp having a definite distribution curve, and situated at a definite height above a horizontal plane, to determine the illumination at any point of the plane:

In Figure 1 (drawn full scale), let O be the centre of the lamp having the distribution curve ABE, and let MX' be the surface, drawn at a vertical distance OM, below OX, such that $K . OM =$ the distance in feet of the surface below the lamp, K being the equating constant, while the candle-power along any radius, as OP, is given by $K' . OB$, OB being measured in the same units as is OM, — say in centimeters.

The intensity of illumination at the point P in the horizontal plane will be:

$$e = \frac{K' . OB}{(K . OP)^2} \cos QPO.$$

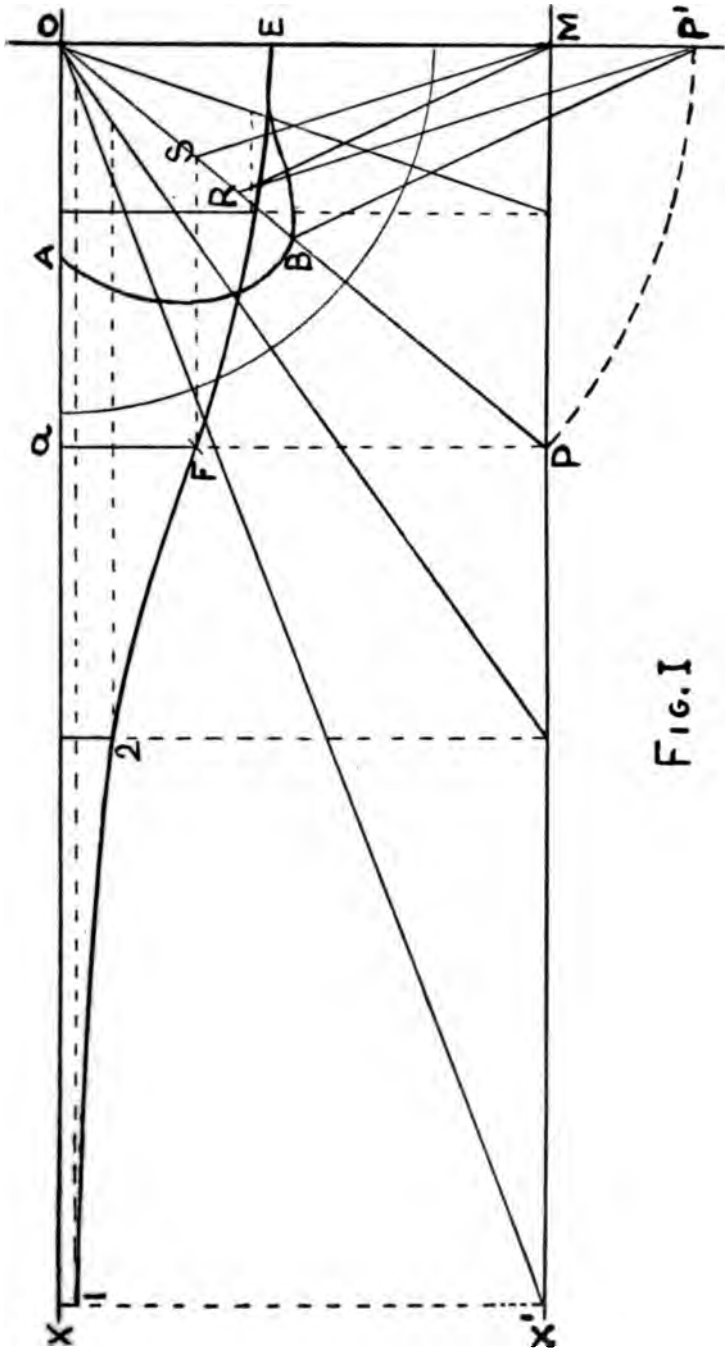

FIG. I

Now, let us lay off $OP' = OP$, join B and P', and through M draw parallel to BP', giving us point R. Connect R and P', and through M draw a parallel to RP' and we obtain a point S, and we have:

$$OS = OB\left(\frac{OM}{OP}\right)^2.$$

If through S we draw parallel to OX until we reach PQ at F, we shall have:

$$QF = OS \cos QPO = OB\left(\frac{OM}{OP}\right)^2 \cos QPO,$$

and it follows that

$$e = \frac{K'}{(K \cdot OM)^2} QF = \frac{K'}{h^2} QF,$$

h being the true height of the lamp above the plane in feet.

Continuing this process with successive radii, we obtain a curve, as 1, 2, F, E, having O as the origin, OX and OM as axes of abscissæ and ordinates respectively, such that the abscissa of any point multiplied by K gives the distance of the point from the foot of the perpendicular through the axis of the lamp, and the ordinate multiplied by K'/h^2 gives the illumination at the point in candle-feet. It is obvious that, if a given type of lamp or globe always gives the same distribution curve, that the above construction gives a plot which will be suitable for any candle-power and any height of lamp, the values of the equating constants K and K' being changed to correspond. If a point receives light from more than one source, it is sufficient to sum up the illuminations received from the several sources.

In the figure, if $K = 1$, *i.e.*, if 1 cm. = 1 ft. and $K' = 5$, *i.e.*, if 1 cm. = 5 candle-power, then the height of the lamp will be 6.5 feet above the plane, the illumination at the point P, distant 5.4 feet from the foot of the perpendicular, will be:

$$e = \frac{K'}{h^2} QF = \frac{5}{(6.5)^2}(1.8) = 0.21 \text{ candle-feet.}$$

This construction was originally due to Loppé.[1]

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[1] *Électricien*, 1890, page 936.
Palaz and Patterson, *Industrial Photometry*, page 282.

C. Application of the Method.

A case to which I have recently applied this method, and which furnishes a good example of its powers, is that of the New Meeting House of the First Parish in Concord, Massachusetts.

This building is illustrated in the following plates:

Plate I, a longitudinal section of the building.

Plate II, half end elevations of the auditorium.

Plate III, a plan of the vestry and basement floor.

Plate IV, a plan of the auditorium floor.

Plate V, a plan of the galleries.

Plate VI, showing the auditorium looking east, illuminated by daylight and artificial light.[1]

Plate VII, the same, looking west.

On these plans the location of the lights is indicated by round dots, and on Plates III and IV the small crosses with attached numbers indicate the stations for which the illumination was calculated when planning the installation, and at which it was afterward determined by direct measurement.

The first step in the work was to determine the total candle-power required in the auditorium. This has, allowing for the space occupied by the galleries, organ, etc., approximately 82,000 cubic feet, requiring, on the basis of 0.02 candle-power to the cubic foot, a total of 1,640 candle-power. It was intended to use twenty No. 3555, thirty-four No. 3105 and one No. 1600 Holophane globes, having absorption, respectively, of 13.8 and 12.1 per cent., while the No. 1600, which had not been measured, was assumed to have the same as the 3555's. Allowing for the relative quantities of the several globes, this gave a mean percentage of 12.7, and, accordingly, the candle-power required would be increased to 1,848, while the amount actually used was 1,862, as this divided up better, being at the same time on the safe side.

The No. 3555 is an 8-inch ball, intended for pendant use; the No. 3105 is a 6.5-inch ball, for upright use, and the No. 1600 is a two-piece 16-inch sphere, for pendant use. The distribution curves

[1] In making the negative for the daylight picture on this plate, the plate was inadvertently reversed in the holder, so that left and right are reversed, and there has been no opportunity to make another exposure.

of the first two styles will be found in Part I,[1] pages 198 and 210, respectively. The 16-inch ball has a distribution not widely different from that of the 8-inch pendant spheres, and as but one was used, and as this one was located in the centre of a cluster, it was deemed unnecessary to make a special plot.

The two illumination curves are given in Figure 2.

The general scheme of lighting was to be — a central cluster, a row of ceiling lights on either side below the galleries, and a row of side brackets over the galleries between the windows.

In the centre of the auditorium was placed the 16-inch ball containing a 150 C. P. lamp, and around it, on a radius of 3 feet, a circle of eight of the No. 3555 balls, each containing a 50 C. P. lamp, the mean distance below the ceiling being about 3 feet.

Under the galleries, spaced midway between the windows and close against the ceiling, were placed No. 3550 balls (which are the same as No. 3555's, only fitted for a 4-inch shade holder, instead of a 5-inch), each containing a 32 C. P. lamp.

Over the galleries between the windows was placed a row of two-armed brackets, carrying No. 3105 globes with 32 C. P. lamps. The height of these brackets from the gallery floor was carefully fixed, so that the body of the auditorium was shielded, so far as possible, from the direct rays of the lights by the screen formed by the gallery rail (for the centre of the auditorium floor was going to be high in illumination at the best), while at the same time the rays were allowed to reach as far as possible under the opposite gallery, to assist in the illumination at that point. It is obvious that this consideration determined the height within very narrow limits; the illumination, however, came out very uniform, and far better than would have been obtained had the lamps been placed a foot or a foot and a half higher.

On the east wall of the building, right and left of the organ box, were placed similar brackets; on the organ front, two three-armed brackets, with similar globes and 16 C. P. lamps; on the posts at the foot of the gallery stairs and between the fly doors were put single-armed brackets, similarly fitted; while on the ceiling under the galleries, opposite the landings of the stairs, were put No. 3550 globes, as well as along the sides, only nearer to the front of the gallery. The arch behind the pulpit was lighted with five 10 C. P. frosted

[1] *Loc. cit.*

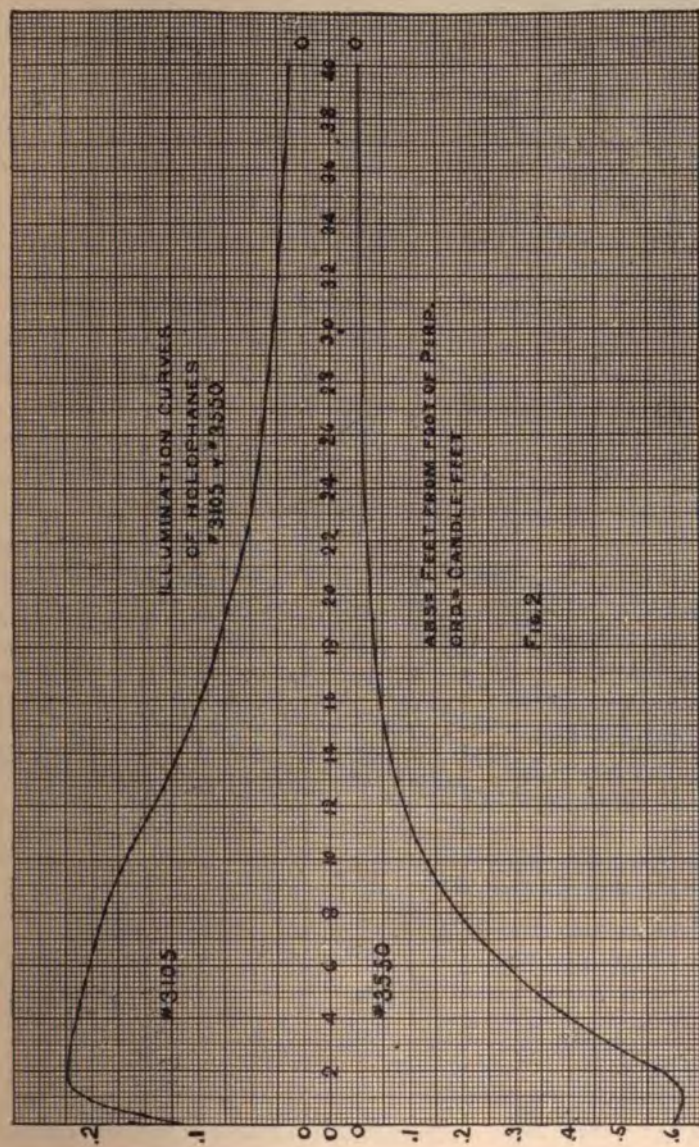
ILLUMINATION CURVES
OF HOLOPHANES
#3105 & #3550
#3105
#3550
ABSS FEET FROM FOOT OF PERP.
ORDS CANDLE-FEET
Fig. 2

FIGURE 2.

lamps, wholly concealed from view, these brightening up that point but adding little to the general illumination.

The auditorium is finished in a very delicate blue tint on float-scoured plastering. The ceiling is slightly curved, finished to a light cream, the cornice white, and all woodwork and trimmings white. Behind the pulpit the finish is gold leaf, with a matt surface and white trimmings, so that the only dark portions are the blue carpet, the California red-wood pews, and the mahogany pulpit and organ case at opposite ends of the auditorium.

Some careful measurements upon finish of this nature indicated that one might safely count on an increase of about seventy-five per cent. over the calculated illumination due to diffuse reflection.

A surface upon which to lay out the illumination was now chosen at 4 feet above the floor, that being about the average height of hymn books during singing by the congregation.

Several typical points were now chosen, the lights affecting these carefully located on the building plans (though no light more than 50 feet away was considered), the distances measured, and the illumination determined. The location of the lights was then changed somewhat and the calculation repeated, the location finally chosen being that which on the average turned out best; it being decided to keep, so far as possible, between the values of 1.0 and 1.5 candle-feet.

Thus, suppose we consider Station 9, which is shown on Plate IV; the lamps affecting this are shown marked with Roman numerals on Plates IV and V. Table I shows the final estimate.

TABLE I.

Lamp No.	Distance in feet from foot of perpendicular.	Illumination in candle-feet.
1	29.0	.0045
2	15.5	.0525
3	3.0	.4800
4	11 0	.1100
5	24.5	.0200
6	Shaded	.0000
7	30.0	.0200
8	52.0	....
9	45.0	.0090
10	44 0	.0100
11	45.0	.0090
12	49.0	.0050

The illumination sums up to 0.72 candle-feet. Increase this by 75 per cent., and it is 1.26 candle-feet, a number fairly within our limits.

It was found afterward by measurement that at this station the actual illumination was 1.24 candle-feet, a difference of less than 2 per cent. This, I may add, is an exceptionally good point.

When this exact location for the lights had been determined, large scale plots of the illumination curves were made, and the illumination at seventy-five stations was calculated, to be sure that no serious discrepancies had crept in. These seventy-five stations were all on one side of the auditorium, it being assumed that the other side would be symmetrical with the first.

D. Measurement of the Illumination.

For the determination of the illumination obtained, I used a Leonhard Weber Portable Photometer.[1] The white card supplied by the makers was used and no opal screen was inserted, as it was

[1] For description, see W. F. Stine, Photometrical Measurements.

possible to get readings without one. Instead of the benzine standard belonging to the instrument, a small incandescent lamp was used. This lamp had been aged and was run at considerably less than its rated voltage, being supplied from a good-sized storage battery of three cells. The voltage on the lamp was 3.50, being maintained constant by the aid of a suitable, finely divided resistance and a carefully calibrated Weston voltmeter. This secondary standard was calibrated against a Hefner Standard lamp and a curve (Figure 3) drawn giving directly the illumination on the white card in terms of the graduated scale on the Photometer. Because of the color difference between the Hefner and incandescent lamps, it was found necessary to use the red and green diaphragms in the eyepiece during calibration, but for all the rest of the work the colors were so nearly alike that the clear eyepiece was entirely satisfactory. Table II gives the values found during calibration.

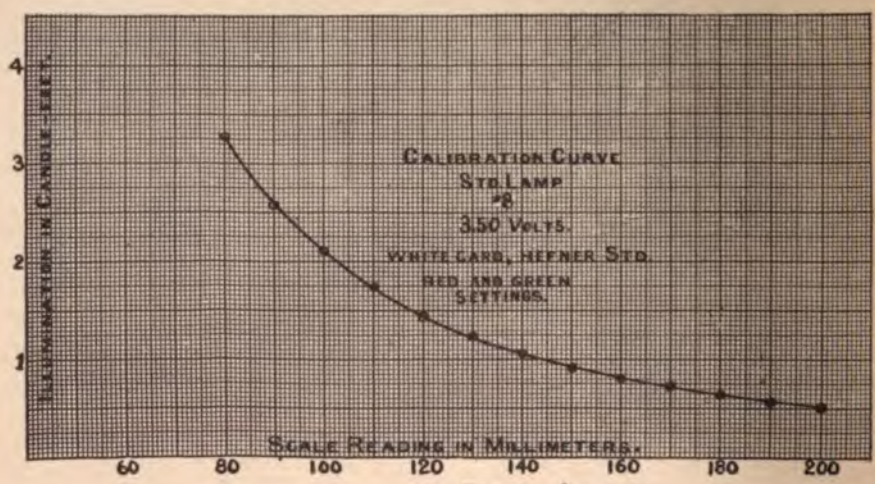

Figure 3.

TABLE II.

Scale reading in mms.	Illumination on Card.	
	Before test.	After test.
80	3.28	3.25
90	2.58	2.60
100	2.10	2.11
110	1.73	1.70
120	1.45	1.43
130	1.25	1.28
140	1.07	1.04
150	.930	.900
160	.822	.817
170	.731	.735
180	.654	.649
190	.580	.577
200	.523	.520

When in use the photometer was mounted on a tripod and fitted with a swinging arm, so that the white card could always be brought into the same position with reference to the photometer. Settings could be made with rapidity and ease, in every case a series of settings being made and the mean recorded. The principal difficulty found was in getting the card and Photometer into the proper relative positions without shading the card from the light of some one of the nearer lamps, but in the great majority of cases this was accomplished finally. At Stations 19, 23, 27, 28, and 31, however, there was a certain small shading effect which was found unavoidable.

Table III gives a summary of the results. The first column gives the number of the station, the second the calculated illumination, the third the same quantity as measured, and the last the percentage difference between them.

TABLE III.

No. of station.	Illumination as Calculated.	Illumination as Measured.	Per cent. difference.	No. of station.	Illumination as Calculated.	Illumination as Measured.	Per cent. difference.
1	0.79	0.75	5.0	43	1.30	1.32	1.5
2	1.03	0.98	5.0	44	1.20	1.24	3.2
3	1.08	1.10	1.8	45	1.17	1.20	2.5
4	1.26	1.27	0.8	46	1.15	1.12	2.7
5	1.10	1.00	10.0	47	1.22	1.26	3.2
6	0.98	1.00	2.0	48	1.31	1.38	5.1
7	1.12	1.00	12.0	49	1.58	1.49	6.0
8	1.14	1.14	0.0	50	1.50	1.56	3.8
9	1.26	1.24	1.6	51	1.61	1.69	5.0
10	1.23	1.18	2.8	52	1.51	1.56	3.2
11	1.08	1.04	3.8	53	1.54	1.50	2.7
12	1.17	1.10	6.4	54	1.40	1.44	2.8
13	1.29	1.32	2.3	55	1.32	1.39	5.0
14	1.21	1.19	1.7	56	1.20	1.26	3.2
15	1.12	1.16	3.5	57	1.10	1.12	1.8
16	1.36	1.24	9.7	58	0.80	0.90	11.1
17	1.45	1.47	1.4	59	0.79	0.95	16.8
18	1.46	1.52	4.0	60	0.97	1.20	19.2
19	1.09	1.00	9.0	61	0.88	1.18	25.4
20	1.16	1.20	3.3	62	0.85	1.16	25.9
21	1.12	1.17	4.3	63	0.84	1.17	27.2
22	1.00	1.05	4.8	64	0.89	1.17	23.9
23	1.03	0.97	6.2	65	0.85	0.99	14.1
24	1.23	1.19	3.4	66	0.97	1.10	11.8
25	1.32	1.29	2.3	67	0.93	1.05	11.4
26	1.26	1.20	5.0	68	0.98	1.09	10.1
27	1.15	1.06	8.5	69	1.04	1.11	6.3
28	1.06	0.98	8.1	70	0.82	0.90	8.9
29	1.06	1.05	0.9	71	0.90	0.96	6.3
30	1.13	1.11	1.8	72	0.70	0.75	6.6
31	1.13	1.09	8.3	73	0.70	0.80	12.5
32	1.16	1.07	8.4	74	1.00	1.00	0.0
33	1.20	1.25	4.0	75	1.10	1.20	8.3
34	1.26	1.35	6.7				
35	1.28	1.36	5.9	76	0.80	0.86	7.0
36	1.27	1.21	5.0	77	0.82	0.87	5.8
37	1.14	1.20	5.0	78	0.86	0.77	11.7
38	1.03	1.08	4.6	79	0.72	0.81	11.1
39	1.00	0.95	5.3	80	0.91	0.80	13.8
40	1.20	1.25	4.0	81	0.95	0.97	2.1
41	1.34	1.31	2.3	82	1.13	1.10	2.7
42	1.36	1.30	4.6	83	1.10	1.09	0.9

E. Discussion of Results.

In this table the mean value of the percentage difference between measured and calculated values is 6.6 per cent., the maximum being 27.2 per cent. and the minimum 0.0 per cent. There are, however, only seventeen stations where the difference exceeds 10 per cent., and many of these can be readily accounted for. Thus, Stations 58 to 68, inclusive, are those where the greatest difference exists, and these are the very ones which are most affected by the five small hidden lamps behind the arch, back of the pulpit, the effect of which was not taken into account in the calculation; as their exact location depended upon the detail of the plaster and *papier-maché* work, which was not at hand till long after the calculations were made. These lamps seriously affect points 60, 61, 62, 63 and 64, and I, of course, relied upon them to bring up the illumination where it belonged; but I doubt if they would have had a large effect upon the remainder of the group, and doubtless some others, had it not been for the large amount of *gold leaf* used behind the pulpit, which was an after thought, not put on until almost the last moment before dedication, and the reflection of which I know to be large, but which naturally was not allowed for. I have not thought it wise to recalculate these points, as it is interesting to see what sort of an effect will arise from such changes.

Again, Stations 76 to 83 are in the vestibule, where the tint on the walls is *buff*. In this case no allowance for reflection was made, as the tint was a late decision. I imagine that 78, 79, and 80 are more affected, because they are at those points where the diffuse reflection is proportionately greater. Stations 81, 82, and 83 are fairly close under the dish in the centre of the ceiling, and 76 and 77, to the ball in the alcove. If we omit Stations 58 to 68, inclusive, the percentage difference falls from 6.6 per cent. to 4.8 per cent., and the maximum difference will be 13.8 (this being one of the vestibule stations).

There are, as calculated, twelve stations where the illumination falls under our lower limit, because of shading by columns, etc. (this omits Stations 60, 61, 62, 63 and 64, for the reason noted above, and all stations beyond 75, because the same limits were not there imposed as in the auditorium), and four which rise above the upper limit.

The measurements give similarly twelve falling under and three rising above.

The mean value as calculated, again omitting the same points, is 1.16 candle-feet; by the measurements it is 1.17.

As calculated, the highest value is 1.61, the lowest 0.70; while by the measurements the highest one is 1.69; the lowest, 0.75.

In view of this, I think it fair to say that where the value of the reflection coefficient is fairly well known, and where this type of shade is used, one can, with careful work, come within about 6 per cent. of his calculations.

Plate III shows a number of stations marked in the vestry and parlor. The vestry has, as Plate I shows, an arched ceiling. It is finished with green walls, float-scoured, and with red-oak wainscot, doors, and trimmings.

I would like to have lighted this by concealed lamps behind the cornice (which just shows on Plate I), but it was not deemed best. It is lighted by a 150 C. P. lamp in a 14-inch Holophane ball, hung in the centre of the ceiling, and four two-branch side brackets on the walls, as shown, fitted with 32 C. P. lamps and No. 3105 globes. No calculations were made for this room (except candle-power per cubic foot, which was made to have a value of .022). The measurements at the marked points give a mean value of 2.1 candle-feet, ranging between a maximum under the ball of 2.29, to a minimum of 1.88 on the diagonal midway between ball and corner of the room.

Calculation of a number of points seems to show a value of diffuse reflection from the walls of about 35 to 40 per cent.

Similarly in the parlor, which is finished with terra cotta walls — white, flat ceiling and white trimmings — the folding doors being paneled with tapestry, the mean illumination on the floor at the marked points is 2.25 candle-feet (produced by two ceiling clusters of four 16 candle-power lamps each, fitted with pendant 6½-inch Holophane, Class B, balls), and a calculation of the illumination at a number of points suggests a value of diffuse reflection of about 45 per cent.

In neither of these rooms was it thought worth while to design the illumination with the care used in the case of the main auditorium, and higher values were allowed because the varied uses of the two rooms made a stronger illumination at times desirable.

In another case a hall was to be lighted, the location of the lights being fixed by the wiring, which was already in place; but it was desired to improve the illumination, which was rather poor; due to the facts — first, that the lamps, which originally were simply frosted bulbs, did not distribute in the proper manner; and second, that the candle-power per cubic foot was low. The hall is approximately 48′ × 60′ × 24′ high; it is used for public meetings, dances, lectures, theatrical and other entertainments, etc. The lamps were arranged in a line around the sides of the hall, on the ceiling close to the walls, and in the centre of the ceiling was placed a circle of twelve lights, the lamps hanging about 3 feet down. Under these conditions the effect was something as follows — there was a marked bright spot in the centre, and the illumination fell off gradually toward the walls, in no place being over .85 candle-foot, and the average being about .65 candle-foot. The change made was to replace the side lights by clear bulbs; to make the central ring double the diameter of the original (or 18′), and to put clear glass, 50 candle-power lamps there. This done, the side lamps were then fitted alternately with Holophane stalactites, No. 3150 (throwing the maximum light off at 45°) and No. 3350 (throwing it directly downward), while the central ring was fitted with dishes of similarly alternate action. The result was that the illumination was raised to a mean value of 2.00 candle-feet, the maximum found (out of seventy-five equi-distant points) being 2.12, and the minimum being 1.92.

It is just as easy to calculate what the result will be in simple cases, using opal globes, ground glass balls, etc., as with Holophanes, because the distribution curves are similar in different azimuths; but it is not so simple to calculate and produce a given scheme, because one does not have the same effective method of producing various distribution curves in the same character of globe, and of combining these according to necessities of the case. Similarly, one can by many types of reflectors produce distribution curves as desired, but diffusion is either absent or imperfect; and in many cases the distribution curves differ in different shades and in different azimuths in the same shade, so that each shade strictly ought to be adjusted to exactly the desired position and then always returned to the same. With the Holophanes all this difficulty is avoided.

Of course, the Holophane is not always the most advisable thing to use, any more than is a given type of anything else always the

best ; but I think that it is likely to prove the most generally useful, as well as the most efficient and certain of the aids toward producing a satisfactory illumination of an interior which we possess at the present time.

AN APPARATUS FOR THE RAPID COMPARISON OF VOLTMETERS.

By F. A. LAWS and W. D. COOLIDGE.

In connection with the work of instruction in Electrical Engineering at the Massachusetts Institute of Technology, between seventy and eighty portable voltmeters and ammeters are employed. These instruments are of the best types, and the class of work demanded of the students requires that their errors be known. Consequently it has been necessary to develop a ready means of calibration. We shall here describe our apparatus for comparing direct current voltmeters with a standard instrument. This is done with the hope that the plan of the arrangement used will be of service to others who must keep track of large numbers of measuring instruments.

The apparatus to be described places at the immediate disposal of the operator any voltage between zero and three thousand. This very considerable range demands that proper safety devices be employed to protect the observer from accident and the instruments from injury. The former is rendered the more imperative by the fact that the apparatus is used by students as well as by instructors, and is of necessity situated in a crowded laboratory.

In the diagram (Figure 1) D_1 and D_2 are two similar dynamos, built by the Holtzer Cabot Co. The frames are those of stock machines; the fields are separately excited from a 110-volt circuit; the armatures are specially wound, so that at 1,600 revolutions per minute each machine has an E. M. F. of 1,500 volts, the current capacity being $\frac{1}{4}$ ampere. In order that there shall be little fluctuation of the voltage, the commutators have a large number of segments, 150.

The dynamos are connected to an intermediate shaft, which is supported by independent, self-oiling bearings, and carries a balance wheel, *W*, weighing 100 lbs.; flexible couplings, c_1 and c_2, are provided.

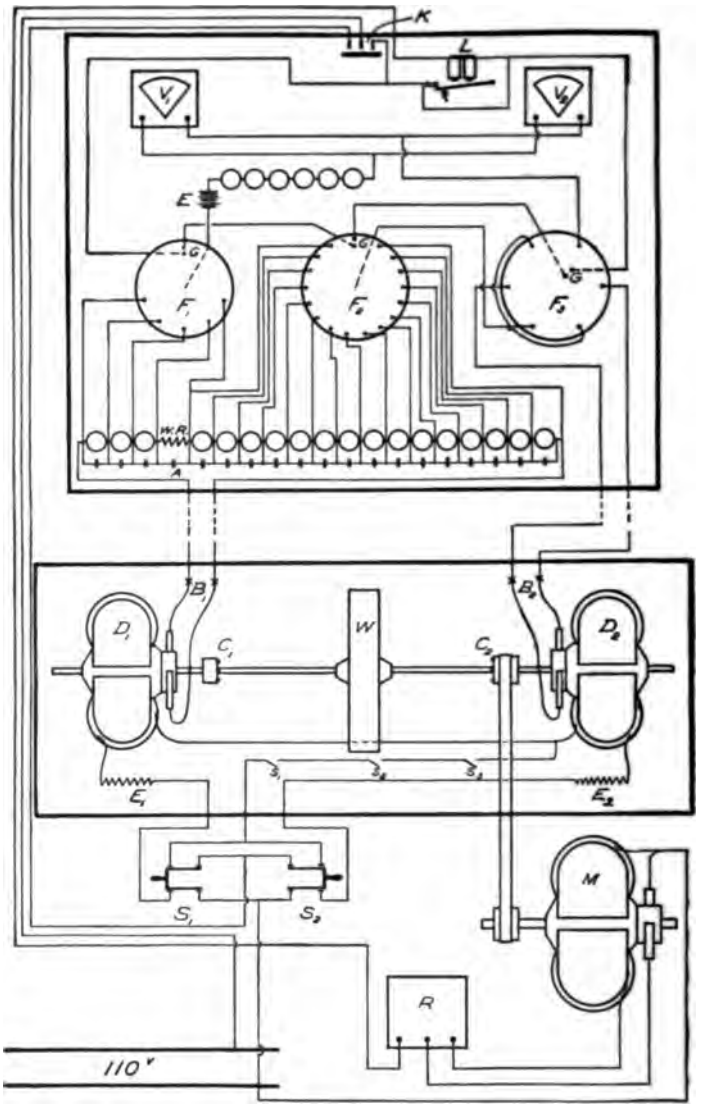

FIG. 1. — DIAGRAM OF THE ELECTRICAL CONNECTIONS IN THE APPARATUS.

To minimize the vibration, the dynamos and intermediate shaft are bolted to a solid framework, very carefully lined up, and supported on pads of hair felt. Power for driving the machines is furnished by a 110-volt direct current motor, provided with an under-load-overload starting rheostat, R.

The dynamos are placed in a protective case. This is provided with windows at the side, and the top is formed of three doors. Those at the ends are glazed, and permit the examination of the machines. The middle door carries the switches, S_1 and S_2, the field rheostats, E_1 and E_2, and the starting rheostat, R. Each door is provided with a lock, but in order to render accident impossible, a safety device is added. On the inside of each door is screwed a brass bar, which when the door is closed completes the circuit between two contact springs. The three breaks, s_1, s_2 and s_3, are in series with the common return from the dynamo fields; consequently, opening the case removes the voltage from the machines. Over-load on the machines is prevented by magnetic circuit breakers, B_1, B_2. From B_1 and B_2 the high potential leads run to the calibrating case containing the switches, F_1, F_2, F_3. Those from Machine 1 are connected to a high resistance drop wire, consisting of an adjustable water rheostat, *W. R.*, and 18 incandescent lamps in series. The first three lamps (counting from the left) are 110-volt, 32 c. p.; the other fifteen 220-volt, 16 c. p. The water rheostat has a maximum resistance somewhat greater than that of a 110-volt, 32 c. p. lamp. With 1,500 volts applied to the potential wire, the drop in each 220-volt lamp is approximately 100 volts, in each of the 110-volt lamps, 30 volts, and in the water rheostat, from 0 to 30 volts, according to its adjustment. By means of the 5-point switch, F_1, and the water rheostat, it is possible to tap off from the drop wire any voltage from 0 to 120 volts, and by means of the 16-point switch, F_2, to add to this in steps of 100 volts until the total is 1,500 volts. Then the switch F_3 may be used to put the second machine directly in series with the voltmeter, thus giving 3,000 volts. If F_3 is not used, the machine D_2 runs on open circuit.

The standard voltmeter and the unknown are placed in parallel in the derived circuit. In series with them are placed six 16 c. p. lamps and a small storage battery of three cells. The battery is so inserted that its E. M. F. opposes that of polarization in the water rheostat; consequently the voltmeter readings can be brought exactly to zero. This is of importance when low range instruments are calibrated.

The insertion of the lamp resistance removes the possibility of leaving the storage cells on a low resistance circuit, even if a low range voltmeter is left connected. Also by the use of this resistance the fineness of adjustment when calibrating low range instruments is much increased; for instance, with a Weston 5-volt voltmeter the distance through which the water rheostat must be moved to attain a given adjustment is about nine times as great as it would otherwise be; the lamps also render it impossible to short circuit the dynamos; when working with high range instruments their resistance is by comparison negligible. The water rheostat was given the particular form shown in Figure 2, in order that there might be no loose high potential wire in the case. The movable electrode is supported by a non-conducting cord, which runs over a vulcanite drum operated from outside the case. To prevent evaporation and to guard against the possibility of the removal of the electrode from the liquid, a wooden cover is firmly fastened to the jars. It will be noticed that the removal of the electrode from the liquid or the breaking of a lamp filament might throw a high voltage upon the voltmeter. To guard against injury to the instrument from this cause the water rheostat and each lamp has in parallel with it a small lighting arrester, (*A*), such as is in common use in telephone work. The thickness of the mica is adjusted so that the arc forms at about 300 volts. The efficiency of this device was tested by breaking circuit successively at the various lamps, and it was found that in all cases the arc was established so quickly that there was no symptom of a violent deflection of the needle.

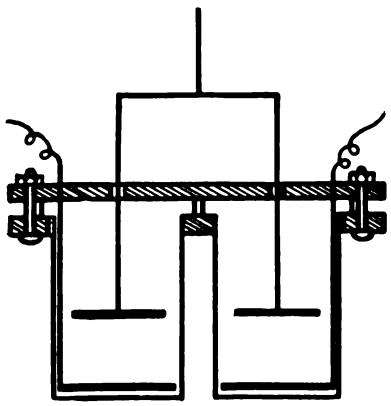

FIG. 2. — SECTION OF THE WATER RHEOSTAT.

The top of the instrument case is closed by a hinged cover which is glazed. Through it project the three vulcanite handles for operating the switches F_1, F_2, F_3. A contact piece, K, screwed to the cover completes the field circuit of the dynamos and motor when the cover is down, but if a person raises the cover, the voltage is thrown off the machines, so that any manipulation is unattended by danger.

The under-load break on the starting rheostat prevents the accidental closing of the motor circuit with no starting resistance inserted, as might be the case if the cover were lowered.

In order to protect the instruments another device was added which renders it impossible to start the motor unless all three switches, F_1, F_2, F_3, stand at zero. This renders it necessary for the operator to always begin at zero and build up the voltage, thereby greatly decreasing the risk of throwing a high voltage on a low voltage instrument through neglecting to note the position of the switches. With this device there is really no excuse for using an improper voltage, for the switches are provided with indices, which show roughly the number of volts applied to the instrument. Re-

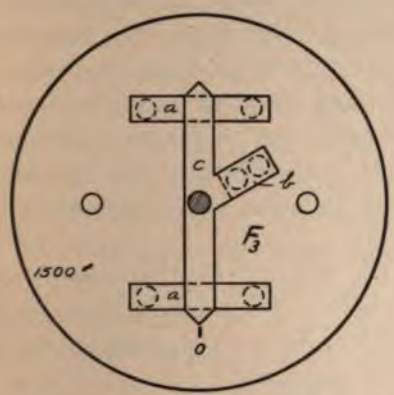

FIG. 3. — SWITCH F_3 IN THE CALIBRATING CASE.

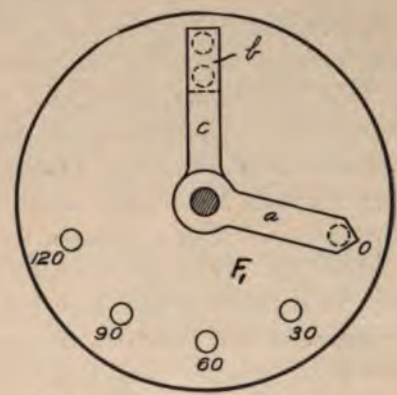

FIG. 4. — SWITCH F_1 IN THE CALIBRATING CASE.

ferring to Figure 1, it will be seen that each of the switches, F_1, F_2, F_3, has a gap G. These gaps are connected in series and brought into the motor circuit. On each of the switches is a second arm, so placed that when the index stands at zero the gap is closed. After the motor is started, a magnetic device, L, closes the main circuit around the breaks and allows the switches to be moved from the zero position. Switches F_1 and F_3 are shown in Figures 3 and 4, where a and b are of spring brass and c of hard rubber.

The dynamo fields are always worked near saturation; this is necessary, for they are supplied from an ordinary lighting circuit. We find as a result of the use of the heavy fly wheel and high excitation that a Weston Voltmeter is readable to $\frac{1}{10}$ volt with ease.

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SOME THERMAL PROPERTIES OF NAPHTHAS AND KEROSENES.

By A. H. GILL and H. R. HEALEY.

In recent years there has been a marked increase in the use of the lighter petroleum oils for fuel purposes, especially for motor vehicles. The data regarding the relative merits of the various naphthas and kerosenes as to their heating value being very meagre, the primary object of this work was to determine these constants. It was also thought desirable to determine some of the other constants, as specific heat and vapor density, but more for scientific interest than for any practical value. Distillations and specific gravity tests were made to characterize the oils, and the flash and fire points of the kerosenes were taken.

For the tests, the so-called 76° Bé. and 62° Bé. naphthas and 135° and 150° fire test kerosenes were used. They were all ordinary commercial oils such as can be readily obtained on the market, and are those usually employed for heating purposes.

The following table gives the specific gravities and the flash and fire points of the kerosenes:

	Degrees Bé.	Specific Gravity.	Flash Point.	Fire Point.
76° Naphtha	76.5°	0.678	.....	.....
62° Naphtha	61.0°	0.733	.....	.....
135° Kerosene.....	48.0°	0.786	125° F.	135° F.
150° Kerosene.....	48.0°	0.788	134° F.	150° F.

Specific Heats.—The specific heats were determined using the apparatus devised by Regnault. This has an inclined cylinder surrounded by a water bath. In this cylinder is a gauze basket in which is placed the substance to be heated, and when at a constant temperature it is quickly lowered into the calorimeter. In ordinary

cases it is the unknown substance which is heated and the calorimeter is filled with water. In this case the procedure was just reversed. The oil to be tested was placed in the calorimeter, and a substance of which the specific heat was known was put in the cylinder. Brass rod about one quarter of an inch in diameter was the material employed, and ten determinations were made of its specific heat. These varied from 0.09198 to 0.09239; the average was 0.09220. This being known, S', the specific heat of the oil is easily obtained from the formula

$$(WS + ws)(t_1 - t_2) = (W'S' + w's')(t_2 - t_0).$$

The naphthas were troublesome on account of the ease with which they evaporated, thus introducing an error into the weight of the oil. To correct this, tests were made to determine the rate of evaporation at the temperature at which the experiments were carried on. As between three and four hundred grams of oil were used, it is believed that with this correction the error was made practically negligible. Another slight error — not compensated for — is the latent heat of evaporation.

A more important correction was for radiation. On account of the slow conductivity of heat by oil, the ordinary quick method of plotting a curve of temperatures and times and drawing a straight line through the highest point parallel to that part of the curve which represents the rate of cooling, could not be used. A method based upon Newton's law of cooling was therefore employed, giving the final formula for rise of temperature $t_2 - t_1 - a(\theta - T)m$, in which t_2 is the final temperature, t_1 the initial temperature, a the rate of change per degree difference between t and θ, θ some constant temperature, T the temperature of the calorimeter, and m the interval in minutes between t_1 and t_2.

It is a well known fact that the specific heats of liquids increase rapidly with temperatures. There was not time enough to examine this variation in detail. The results were as follows:

TABLE SHOWING THE SPECIFIC HEATS OF NAPHTHAS AND KEROSENES.

	10° to 20°.	20° to 30°.
76 Naphtha	0.5375	0.5555
	0.5332	
62 Naphtha		0.5044
		0.5032
		0.5038
135 Kerosene	0.4766	0.4997
	0.4749	0.4938
		0.4949
150 Kerosene		0.4922
		0.4903

From this it would seem that the specific heats increase as the specific gravity decreases.

The agreement of the specific heats of the kerosenes together with the specific gravities and distillation curves, shows that these kerosenes are practically identical except as to flash and fire points, where the 135° kerosene contains a greater amount of more volatile constituents which hardly affect any of the other thermal constants.

It is also well to note the comparatively large differences between the specific heats in a range of temperatures between 10° and 20° C. and those in a range ten degrees higher, *i. e.*, 20° to 30° C. The difference shows very plainly the necessity of stating the range of temperatures along with the specific heats, else all attempts at comparison are practically worthless.

Vapor Density and Molecular Weight. — The petroleum oils are not definite fixed compounds but a mixture of all sorts of hydrocarbons, mostly of the methane series. For this reason, that a certain oil can have no symbol, it might be justly considered unscientific to make molecular weight determinations upon it. However, there are two practical reasons for making the determinations.

The pressure of a mixture of gases is made up of the partial pressures of the constituent gases, and the volume and temperature are the same for all constituents. Hence, the pressure is the only

thing that can vary for the different gases in the mixture, since $PV = RT$.

Now the pressure of each gas depends upon the amount of the gas present (expressed in molecular weights). Thus each different molecular weight is duly represented by its own pressure and weight of substance present. So, therefore, the result obtained is a sum of the molecular weights of the constituents, each constituent having a representation depending upon the amount and molecular weight. In other words, if we assumed the naphthas to be composed of the methane series only, the molecular weight of the naphtha would be nearly the same as that of its principal constituent, or it might express an average of the constituents. Thus 76° naphtha has a molecular weight of 89, which is nearly the molecular weight of hexane, C_6H_{14} (molecular weight, 86), and hexane is known to be the chief constituent of 76° naphtha. And, likewise, octane (molecular weight, 114) is a principal constituent of the heavier 62° naphtha, the molecular weight of which is 112.

The second and more important reason for making the determination was to determine the vapor density. It is desirable to know something about the weight of naphtha vapor in figuring explosive mixtures. This can only be done by determining the vapor density.

For the determination, Victor Meyer's method was employed. The apparatus was the modification used at the Institute, consisting of a small tube inside the regular vaporization tube, through which the bulb of liquid is dropped. A naphthalene bath was used.

The results are as follows:

	62° Naphtha.	76° Naphtha.
	111.8	
	112 3	89.89
	111.6	89.71
Mean	111.9	89.8

Heats of Combustion.

In the burning of an oil there are a number of physical and chemical changes before the final products of combustion are reached. These changes require heat, and the heat thus used should account for the difference between the actual results and the theoretical heat

of combustion figured from the content of carbon and hydrogen. Following along in the order of changes, we have first the raising of the temperature to a point where the oil will vaporize. This includes the specific heat of the oil. Next comes the heat of vaporization. In the burning of a vapor to carbon dioxide and water, it is broken into its elements, carbon and hydrogen. The heat represented by this change is the same as the heat of formation. It is right here that the greatest part of the difference between figured and practical results occurs. According to the theories of thermo-chemistry, every compound has a certain definite intrinsic energy. Energy of elements is assumed to be zero from lack of knowledge. According to the theory of conservation of energy, there can be nothing lost when one system of substances changes into another system, as for instance when methane and oxygen change into carbon dioxide and water. But the sum of the intrinsic energies of the new system is different from that of the first. Therefore there is a difference of energy that must manifest itself, and in the above mentioned change and in chemical reactions in general, it is manifested as heat. In other words, this difference is the heat of combustion of a substance when it reacts completely with oxygen. The heat of formation of a compound is evidently the above mentioned intrinsic energy. It represents the heat given out when elements with zero energy combine to form the new compound. Thus a gram molecule of amorphous carbon uniting with oxygen gives out 97.0 calories. So the heat of formation of a gram molecule of carbon dioxide is —97.0 calories. Likewise, the heat of formation of water is —68.3 calories.

The heat of formation of methane is found as follows:

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$
$$X = -97. - 2 \times 68.3 + 211.9.$$

Thus X, the heat of formation of methane, is — 21.7 calories, and the experimental heat of combustion is 211.9 calories for a gram molecular weight.

It is an experimental fact that in any homologous series of hydrocarbons the heats of combustion increase 1,580 K (centruple calories) for each rise of CH_2 in the composition. So that the heats of combustion of the methane series would be 539 K + n1,580 K for a gram molecular weight when n equals the number of carbon atoms.

Now, figuring out the heat of combustion from the content of carbon and hydrogen would give

$$C_n H_{2n+2} + \frac{(3n+1)}{2} O_2 = nCO_2 + (n+1) H_2O.$$

Then the heat of combustion equals

$$n979K + (n+1)\,683K = (1{,}653n + 683)\,K.$$

The heat of formation is the difference of $(1{,}653n + 683)\,K$ and $(1{,}580n + 539)\,K$, which equals $(144 + 73n)\,K$. Thus we see that the heat of formation of the methane series also has a regular variation for each CH_2. This is $73\,K$.

The next point to consider is the resulting volume of gases after combustion. If the volume is increased there is work done, and for a gram molecule the heat equivalent is $2T$ calories, which follows from the equation $PV = RT$. This amounts to considerable in the combustion of hydrocarbons. For example: $C_n H_{2n+2} + \frac{(3n+1)}{2} O_2 = nCO_2 + (n+1) H_2O$. Hence, volume before combustion equals $\frac{3n+3}{2}$, and the volume after combustion equals $2n + 1$, if the steam does not condense. There is therefore an increase of volume of $\frac{n-1}{2}$. The heat equivalent of this is $\frac{(n-1)}{2} 0.02T$, where T is the absolute temperature. This would vary from zero for methane to over twenty for octane, assuming that the gases pass off at 100° C. The remaining part to consider is whether the water formed passes off as a gas or condenses to a liquid. If it condenses, it gives up an amount of heat (97 K per gram molecule, or 0.6 calories per gram) which it would otherwise have carried off.

In the above discussion an attempt has been made to account for the difference between the actual results and those got by the ordinary methods of figuring by an application of the theories of thermochemistry. There are oftentimes confusing divergences in tables on the heats of combustion. But after the above considerations, it often appears that the results are the same when reduced to the same conditions.

In the experiments on the heats of combustion of the oils, a Junkers' gas calorimeter was used. The oil was burned from a plumber's lamp ("Primus" No. 4). In this lamp an air pressure was produced on the surface of the oil by an attached pump. The oil was thus forced out through a small orifice and through a hot tube, where it was supposed to be vaporized before it reached the flame. There was a tube surrounding the heated tube, through which air was admitted. Thus it gave a vigorous blue flame.

To get the weight of the oil burned, the lamp and contents were weighed before and after the run. The runs were usually twenty minutes, and about thirty grams of oil was burned on an average. From theoretical considerations the variations in the heats of combustion should be very slight, and in fact they were.

The following is a summary of the mean results of the various tests:

SPECIFIC HEATS.

Brass 0.09220

	10° to 20°.	20° to 30°.
76° Naphtha	0.5354	0.5555
62° Naphtha	....	0.5045
135° Kerosene	0.4758	0.4961
150° Kerosene	....	0.4912

VAPOR DENSITIES.

76° Naphtha	44.9
62° Naphtha	56.0

HEATS OF COMBUSTION.

	Cal. per gram.	B. T. U. per lb.
76° Naphtha	10.04	18,080
62° Naphtha	9.92	17,860
135° Kerosene	9.89	17,810
150° Kerosene	10.10	18,290

A SHORT METHOD OF FINDING TIME BY EQUAL ALTITUDES OF TWO STARS.

By G. L. HOSMER.

THE following article is a brief description of a special case of the method of finding time by equal altitudes of a heavenly body. The method given here applies to observations made with such instruments as the engineer's transit or the sextant, but should not be used with instruments of greater precision.

If two equal altitudes of a star be taken, one east and one west of the meridian, and the times noted by a watch, then the mean of the observed times is the watch reading when the star crossed the meridian. If the observations are made on the sun, the above relation is not exactly true, but the mean of the observed times must be corrected for the effect of the sun's change in declination, in order to obtain the time of the sun's meridian passage, or apparent noon. The equation for computing the correction is

$$e = -\frac{t\,\Delta}{15}\left(\frac{\tan\varphi}{\sin t} - \frac{\tan\delta}{\tan t}\right) \qquad (1)$$

$$\text{or, } e = A\,\Delta\tan\varphi + B\,\Delta\tan\delta, \qquad (2)$$

where e = correction to be added.
t = half the elapsed time, in hours.
Δ = hourly change in sun's declination.
δ = sun's declination at noon.
φ = latitude of place.

$$\left.\begin{aligned} A &= -\frac{t}{15\sin t} \\ B &= \frac{t}{15\tan t} \end{aligned}\right\} \text{tabulated quantities.}$$

This method has the advantage that the altitudes themselves are not used, so that errors of the instrument do not enter into the computation. In fact, the observation may be made with a transit which has no vertical arc, provided the horizontal axis can be clamped.

The accuracy is greatest when the observer is on the equator and the declination of the sun or star is zero. Near the pole the method is practically useless.

The disadvantage of the method is that we must wait several hours between the observations. It is proposed to overcome this difficulty by observing on two different stars when they are at the same altitude on opposite sides of the meridian.[1] At the instant when they have equal altitudes, the local sidereal time equals the average right ascension of the two stars, $\frac{a_1 + a_2}{2}$, exactly if they have the same declination, approximately if they have slightly different declinations.

Suppose we select two stars whose right ascensions differ by about six hours and whose declinations are nearly the same. A few minutes before it is time for their average right ascension to come to the meridian, we will observe an altitude of the eastern star and note the time by a watch. We then turn to the western star and wait until it has an altitude equal to the first and note the time. We now take the mean of the observed times as being the watch reading corresponding to the sidereal time, $\frac{a_1 + a_2}{2}$. Now, since the declinations of the two stars differ, we may treat the observations as though we had observed on one star only, and it had changed its right ascension and declination uniformly so as to reach the second position at the time of the second observation. In other words, the known relative position of the two stars has bridged over a long interval of time, so that we have accomplished in a few minutes what would otherwise have taken several hours. If we now take $\Delta = \frac{\delta_2 - \delta_1}{a_1 - a_2}$ = hourly change in declination, we may correct $\frac{a_1 + a_2}{2}$ precisely as for a solar observation. It should be noticed

[1] See an article in Van Nostrand's Engineering Magazine, 1878, by L. Wagoner, describing a method of finding latitude, time and azimuth by observations of two stars at equal altitudes.

that since we are now correcting right ascensions, the sign of e is reversed.

In the case of the sun, the hourly change in declination is always less than one minute; consequently, some approximations have been made in deriving the "equation of equal altitudes" (Equation 2), which will not hold good beyond certain limits. It is necessary, before using the equation for this method, to determine how much the two declinations may safely differ. The following numerical test will serve to indicate the magnitude of the error in this formula:

Suppose two stars of declinations $+ 20°$ and $+ 25°$ have each an altitude of $30°$ at a certain instant of time. We will suppose that the latitude of the place is $+ 45°$. We find for the hour angles, $4^h\ 28^m\ 32.8^s$ and $4^h\ 46^m\ 48.9^s$. Then $2t = 9^h\ 15^m\ 21.7^s = a_1 - a_2$, if the observations were made at this instant. The correction should be $9^m\ 08.05^s$. By the formula we get, taking $\Delta = \frac{18{,}000''}{9.256}$, $e = 9^m\ 07.60^s$. The error in the formula is, then, less than half a second for these unfavorable conditions. Therefore, if the declinations differ by $2°$ or $3°$, and are themselves not greater than about $20°$, the formula is sufficiently accurate for observations made with the engineer's transit. It is important that the interval between the observations should be kept very small, otherwise a correction would have to be introduced to allow for the unequal motion of the two stars.

The disadvantages of this method are that (1) we are limited to stars bright enough to be easily identified, and (2) we are somewhat limited in our choice of positions of stars. It is not always easy to find a pair whose mean right ascension is just what we wish and whose declinations differ by a small amount. If one star is bright and the other faint, we may always observe the bright one first, for it makes little difference whether we observe the east star first at a low altitude, and wait for the west star to come down to this altitude, or whether we observe the west star first at a higher altitude and wait for the east star to rise to this altitude. If we observe the bright star first, then we know the altitude at which we must look for the fainter one, and approximately the time at which it will appear in the field. (Its direction may be estimated by the compass needle.)

It is improbable that this method would be the best one in many cases, but it certainly has advantages, for we can in this way find the local sidereal time with little less accuracy than by a transit across

the meridian and without the trouble of laying out a meridian line by observation. The computation is simpler than that of single altitudes, provided we have at hand the tables giving A and B (Equation 2). We also have the advantage of all the accuracy gained by equal altitudes.

We give the following examples to illustrate the method:

EXAMPLE 1.

February 23, 1902.

Latitude, 42° 28′. Longitude, 4*h*. 44*m*. 14*s*. Observed equal altitudes of α Leonis (Regulus) and α Tauri (Aldebaran).

	h.	*m.*	*s.*		*h.*	*m.*	*s.*
Watch,	8	59	00		8	59	00
Stop watch,		1	59.0			1	42.2
Regulus,	8	57	01.0	Aldebaran,	8	57	17.8

Average = 8*h*. 57*m*. 09.4*s*.

	Right Ascension.			Declination.
	h.	*m.*	*s.*	
Regulus,	10	03	11.6	+ 12° 26′ 30″
Aldebaran,	4	30	19.2	+ 16° 18′ 40″
Average,	7	16	45.4	+ 14° 22′ 35″
Difference,	5	32	52.4	3° 52′ 10″

$$\Delta = \frac{13.930''}{5.548} = 2.511''$$

log Δ 3.3999 *n*	log Δ 3.3999
log *A* 9.4448	log *B* 9.3185
log tan φ 9.9615	log tan δ 9.4088
2.8062	2.1272
640.0*s*.	134.0*s*.
134.0	
506.0*s*.	

— 8*m*. 26.0*s*.

	h.	*m.*	*s.*
Average R. A.,	7	16	45.4
c,		8	26.0
Sidereal time,	7	25	11.4
R. A. "Mean Sun,"	22	10	32.7
Reduced to solar time,	9	14	38.7
		1	30.9
Mean local time,	9	13	07.8
		15	46
Eastern standard time,	8	57	21.8
Average watch reading,	8	57	09.4
Watch slow,			12.4

EXAMPLE 2.

February 15, 1902.

Latitude, 42° 28′. **Longitude**, 4*h*. 44*m*. 14*s*. **Observed equal altitudes of** β **Orionis and** α **Hydræ.**

	Right Ascension.			Declination.	Watch.		
	h.	*m.*	*s.*		*h.*	*m.*	*s.*
α Hydræ,	9	22	48.7	— 8° 14′ 18″	9	19	38
β Orionis,	5	09	51.2	— 8° 19′ 08″	9	20	56
Average,	7	16	20.0	— 8° 16′ 43″	9	20	17.0
Difference,	4	12	57.5	0° 04′ 50″			

$$\Delta = \frac{290''}{4.22} = 68.72''$$

log Δ	1.8371 *n*	log Δ	1.8371 *n*
log *A*	9.4284 *n*	log *B*	9.3579
log tan φ	9.9615	log tan δ	9.1627 *n*
	1.2270		0.3577
	+ 16.9*s*.		2.3*s*.
	+ 2.3		
	+ 19.2*s*.		

	h.	*m.*	*s.*
Average R. A.,	7	16	20.0
e,			19.2
Sidereal time,	7	16	00.8
R. A. "Mean Sun,"	21	39	00.2
Reduction to solar time,	9	37	00.6
		1	34.5
Mean local time,	9	35	26.1
		15	46
Eastern standard time,	9	19	40.1
Average watch reading,	9	20	17.0
Watch fast,			36.9

TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

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PROCEEDINGS OF THE SOCIETY OF ARTS.

FORTIETH YEAR, 1901–1902.

BOSTON, January 6, 1902.

THE 560th regular meeting of the SOCIETY OF ARTS was held on this day at 8 P.M., in the Walker Building, Colonel Hewins presiding. Two hundred and fifty persons were present.

At the conclusion of the regular business, Professor George E. Hale, Director of the Yerkes Observatory, addressed the Society on "The New Star in Perseus."

The speaker referred to the discovery of the new star in Casseopeia, by Tycho Brahe, November 11, 1572, and its influence on astronomy, likewise of the exceedingly primitive instruments available at that time for the investigation of such phenomena. Many new stars have been discovered since then, the latest being the new star in Perseus, on the evening of February 21–22, 1901. Dr. Anderson, of Edinborough, noticed on that evening in the Constellation of

Perseus a star equal in brightness to the Pole star. The brightness increased about 10,000 in three days, then began to fade away, at first gradually, afterwards fluctuating in intensity, until its final disappearance in May. Its color was white, then red. The light of the star must have been increased with great rapidity, for an examination of the photographs of this region of the heavens made on and before February 19th, at the Harvard Observatory, failed to show any trace of the star, though the plates showed stars as faint as the eleventh magnitude. A photograph of the new star with the 40″ refractor of the Yerkes Observatory was shown.

The speaker referred to the rise of spectroscopy and its bearing on the solution of astronomical problems as to the nature and condition of heavenly bodies, problems which until 1860 seemed beyond the power of investigation. The production of continuous bright and dark line spectra were explained, and slides were shown to illustrate the life-history of a star as it can be gleaned only from a study of the gradual changes in its spectrum. This method of analysis was applied to the new star during the weeks following its appearance, and the changes in physical condition which it underwent were explained by slides thrown on the screen. By the first of June the spectrum had changed to one characteristic of gaseous nebula. During these months the change in the true position of the lines in the spectrum had shown the star to be in the motion away from the earth at a small velocity determined by the Doppler principle.

On August 23d, Professor Wolf, of Heidelberg, discovered a condensation of the faint nebula near the star. No further observations were made until September 26th, when Professor Ritchey, of the Yerkes Observatory, succeeded in obtaining, after a four-hour exposure with the 20″ reflector, a photograph showing nebula surrounding the star with four principal condensations of faint nebula. Owing to cloudy weather, no further photographs were secured by him. On November 7th, Professor Perrine, of the Lick Observatory, obtained a photograph showing marked changes of position in the four pronounced condensations, the change in position corresponding to velocities of the order of the velocity of light. The entire nebulosity had expanded outward.

Some beautiful slides of nebulæ were shown, among them the great nebula of Orion, the nebula in Andromeda, and the spiral nebulæ. The latter part of the lecture was devoted to a discussion

of the various hypotheses regarding the cause of the sudden appearance of new stars.

On the motion of Professor Clifford, the thanks of the Society were extended to Professor Hale for his admirable presentation of this fascinating subject.

BOSTON, January 23, 1902.

The 561st meeting of the SOCIETY OF ARTS was held on this day, in the Walker Building, Professor Cross presiding. One hundred and sixty-five persons were present. Mr. George R. Hardy, Engineer, N. Y., N. H., & H. R. R., and Mr. Henry S. Anderson, Manager United Electric Light Company, Springfield, were elected to Associate Membership.

Mr. Calvin W. Rice, of New York City, spoke on the "Utilization of Electricity in Mines." In the early days of mining, hydraulic transmission of power was used. Later arose the pneumatic system, as a consequence of the development of the air drill and hoist, and the fact that the spent air assisted somewhat in the ventilation. Following the pneumatic system came steam, and lastly, rope driving. In all these methods the transmission is limited, not alone by distance but also on account of the scarcity of wood and coal, and at high elevations the scarcity of water. It was only natural with the development of the application of electricity to industrial work, that attention should be directed to its utilization in mining. With electric power, there is no reasonable limit to the distance of transmission, and hence it becomes possible to locate the power plant either near the water supply or else near the ore bodies.

The main progress in the use of electricity has been made during the last ten years. The first system was direct current at 250 volts. During the last five years alternating currents have been introduced for coal cutters, hoists, and pumps. The voltage has been raised from 250 to 500 volts, so as to be uniform with the street railways. Considerable discussion has arisen as to the wisdom of such high voltages, owing to the danger to life. The shafts or tunnels are very low, and the frequent explosions, together with excessive amount of water, render the insulation very poor.

One of the most valuable applications of electricity in mining is electric haulage. The engines are most substantially built to haul the required loads, and of low construction to pass through the low tunnels. Direct currents are alone used, since no successful alternating current motor for such work has yet been constructed.

The general installations in mines may be classified as follows: (1) Rope haulage and steam for other purposes; (2) electric haulage and compressed air for other purposes; (3) electric haulage and electricity for other purposes.

Many slides were shown of electric locomotives, methods of installation, and curious electrical devices. A vote of thanks was given to Mr. Rice for his interesting paper.

BOSTON, February 13, 1902.

The 562d regular meeting of the SOCIETY OF ARTS was held, in the Walker Building, on this day at 8 P.M., President Pritchett presiding. Three hundred and fifty persons were present.

The report of the previous meeting was read and approved. The following papers were presented by title: "Some Thermal Properties of Naphthas and Kerosenes," by A. H. Gill and H. R. Healy; "Apparatus for the Rapid Comparison of Voltmeters," by Professor F. A. Laws and Dr. W. D. Coolidge; "A Study of Certain Shades and Globes for Electric Lights as Used in Interior Illumination, Part 2," by William Lincoln Smith, S. B.

Professor W. H. Burr, of Columbia University, Member of the United States Commission on the Isthmian Canal, spoke on "Some Features of the Isthmian Canal Question." A *résumé* of the lecture will not be given, as the report of the Isthmian Canal Commission for 1899–1901 has been placed on the files of the Society. An interesting discussion followed.

Dr. Pritchett expressed to the speaker the gratitude of the audience for the admirable, instructive, and interesting lecture.

BOSTON, February 25, 1902.

The 563d regular meeting of the SOCIETY OF ARTS was held on this day at the usual hour, in the Walker Building, Mr. Desmond FitzGerald presiding. Three hundred persons were present.

At the conclusion of the regular business, Mr. William Barclay Parsons, Chief Engineer of the New York Subway, gave an illustrated lecture on "Engineering in China." The first part of the lecture was devoted to a consideration of the Chinese as engineers, the subject being treated under the heads of transportation, construction, and mechanics. For the inland commerce the rivers are the chief highways. Junks of the most primitive construction are used, propelled by oar, sail, and sometimes by stern paddle wheel. Although the streams are often shallow and filled with obstructions, no attempt has ever been made to render the navigation less dangerous. For coast and sea-going work, a junk of large and strong proportions is used, furnished with water-tight compartments. This bulkhead construction is known to have been used in China since the thirteenth century, and was mentioned by Mr. Parsons as one of the number of devices which are assumed to be of modern occidental origin. The land transportation into the interior is in the north by cart drawn by an ox or horse, in the south by wheelbarrow, and as a consequence there are no road systems, the highways being often almost impassable. A large part of the inland commerce is carried on the backs of coolies.

The Chinese have been acquainted, apparently, for many centuries with the principles of good engineering along static lines. This is learned from an examination of the old bridges, pagodas, and great walls. Indeed, the arch construction is of the highest order, and proves that the principles involved were known long before the time of the Romans, to whom arch construction is attributed. On dynamic lines, however, the greatest ignorance is manifested, and it will be in the development of the mines, the improvements in the methods of transportation of people and goods, and in the applications of machines of all kinds, that the foreign influence will be most felt.

The latter part of the lecture was devoted to a discussion of the plans which have been made to connect the large industrial centres of the empire. On a map it was shown that the Yangtze River, running east and west, and navigable for 1,500 miles, practically divides the Chinese empire into two halves. To connect the southern and northern halves, a concession has been granted to an American company for a railway from Canton to Hongkong, to connect with the Belgian concession between Hongkong and Peking. The English have a concession from Shanghai on the coast to Nanking, which will be

extended in time to connect with the Canton-Peking line. Rights have been granted for a line from Shanghai northward to Tientsin, and a line will ultimately be projected from Shanghai to Canton.

These proposed railway systems traverse a region rich in mineral wealth, coal, iron, petroleum, gold, silver, and other metals.

On the motion of Professor Swain, a vote of thanks was extended to Mr. Parsons.

BOSTON, March 13, 1902.

The 564th regular meeting was held on this day, in the Rogers Building, at the usual hour, Mr. Blodgett presiding. Ninety-one persons were present.

The following persons were elected to Associate Membership: C. R. Gyzander, H. L. Morse, R. R. Goodell, Ernest W. Day.

The following paper was presented by title: "A Short Method of Finding Time by Equal Altitudes of Two Stars," by George L. Hosmer.

Dr. Heinrich O. Hofman, Professor of Metallurgy at the Institute, gave a most interesting and valuable lecture on "Aluminum as a Reducing and a Heat Producing Agent." The lecture was illustrated by stereopticon and experiments. The paper will shortly appear in the TECHNOLOGY QUARTERLY.[1]

GEORGE V. WENDELL, *Secretary.*

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[1] See pages 93–104 of the current issue.

ALUMINUM AS A REDUCING AND A HEAT-PRODUCING AGENT.

BY H. O. HOFMAN.

Read March 13, 1902.

INTRODUCTORY.

SPEAKING broadly, metals can be said to occur in nature in the native state, or as sulphides (including arsenides, antimonides, etc.) or as oxides.

The metallurgical treatment of base metals in the native state is comparatively simple, as they are already in the state in which they are to be used in the arts. Taking, *e. g.*, native copper ores from Lake Superior, they are crushed and washed in order to eliminate as much as possible the valueless gangue, then the resulting copper concentrate is subjected to a process of fusion, which, at least when considered chemically, is relatively simple.

With sulphides the matter becomes more complicated. There are two ways of attacking the problem. Under the right conditions of temperature, a metal which has a stronger affinity for sulphur can be brought in contact with the sulphide, when this will be decomposed. Thus from galena (PbS), lead is extracted by means of iron, as iron has a greater affinity for sulphur than lead:

$$PbS + Fe = FeS + Pb.$$

The other method available to decompose a sulphide, is to convert it into oxide by roasting, *i. e.*, by heating with access of air. Brass-colored pyrite (FeS_2) is thus readily converted into brownish-red ferric oxide (Fe_2O_3):

$$2FeS_2 + 11O = Fe_2O_3 + 4SO_2.$$

This leads to the third form in which metals occur in nature, *i. e.*, as oxides. In order to obtain the metal from its oxide, this is usually

subjected to a reducing fusion. The common reducing agents are carbon (C) and carbon monoxide (CO). At a low temperature carbon burns to carbon dioxide (CO_2):

$$C + O_2 = CO_2,$$

at a high temperature only to carbon monoxide:

$$C + O = CO.$$

The affinity of carbon for oxygen increases with the temperature; it requires, *e. g.*, carbon heated to over 3000° C., if it is to wrest the oxygen from alumina (Al_2O_3):

$$Al_2O_3 + 3C = Al_2 + 3CO.$$

Carbon monoxide acting as a reducing agent burns to carbon dioxide:

$$CO + O = CO_2.$$

It can, therefore, do satisfactory work only at comparatively low temperatures, of 1000° C. and less.

Beside the usual reducing agents, carbon and carbon monoxide, we can use the different affinities of metals for oxygen for purposes of reduction.[1] The affinity a metal has for oxygen is measured by the amount of heat that is evolved when the metal combines with oxygen. The greater the heat evolved, the stronger will be the compound and, what is the same thing, the more difficult will it be to separate the oxygen again from the metal. As shown in the accompanying table, 1 gramme of aluminum burning to alumina evolves 7,250 calories; 1 gramme of magnesium, only 6,000 calories, and so on down the list. If we bring, *e. g.*, chromic oxide (Cr_2O_3) of a calorific value of 60 together with metallic aluminum and heat the mixture to 1010° C., at which temperature the affinity of aluminum begins to assert itself, aluminum will rob chromic oxide of its oxygen:

$$Cr_2O_3 + Al_2 = Cr_2 + Al_2O_3;$$

the temperature will rise quickly to above 3000° C., and we shall obtain fused metallic chromium and fused alumina.

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[1] Roberts-Austen. Proc. Royal Institution, 1901; Nature, 1901, 64, 360; Proc. Royal Institution, 1893–95, 14, 497; Nature, 1895, 52, 14, 39.
Keller. Jl. Am. Chem. Soc., 1894, 833.

TABLE.

HEAT EVOLVED BY BURNING ONE GRAMME OF THE FOLLOWING ELEMENTS.

Element, 1 gramme.	Product of combustion.	Calories.
Al	Al_2O_3	7,250
Mg	MgO	6,000
Ni	NiO	2,200
Mn	MnO_2	2,110
Fe	Fe_2O_3	1,790
Fe	Fe_3O_4	1,580
Fe	FeO	1,190
Co	CoO	1,090
Cu	CuO	600
Pb	PbO	240
Ba	BaO	90
Cr	Cr_2O_3	60
Ag	Ag_2O	30

ALUMINUM AS A REDUCING AGENT.

The property of aluminum to act as a reducing agent became known soon after Wöhler had isolated the metal in 1827. The earlier investigators worked more with chlorides and fluorides than with oxides. Thus Wöhler[1] in 1858 obtained crystalline compounds of chromium and aluminum; Michel[2] in 1860, compounds of aluminum with manganese, iron, nickel, tungsten, molybdenum and titanium; the brothers Tissier[3] in 1856 reduced the oxides of copper and lead; Vautin[4] in 1892 decomposed galena; Franck[5] in 1898 reduced phosphoric acid, and so on.

The first commercial application of aluminum as a reducing agent

[1] Liebig's Annalen der Chemie, 106, 118.
[2] Liebig's Annalen der Chemie, 113, 248.
[3] Comptes Rendus, 43, 1187.
[4] Journal Society Chemical Industry, 1898, 543.
[5] Stahl und Eisen, 1898, 410; Jl. Iron and Steel Inst., 1898, II, 549; Bull. Soc. Chim., Paris, 1894, 11, 439.

was made by Messrs. Green and Wahl,[1] who, between 1891 and 1893, experimented especially on the production of carbonless manganese. They manufactured considerable quantities of it in 1894–95 at the Disston Works in Tacony, near Philadelphia. A sample of manganese, presented to the Institute by Dr. W. H. Wahl, contains Mn, 96.5%; Fe, 3.0%; Si, 0.5%. The metal is dense and homogeneous; it has a steel-gray color, with a pinkish tint; it is hard and brittle; becomes fissured when cast in iron moulds, but does not oxidize or disintegrate in moist air, as does all manganese that has been reduced by carbon. Such a manganese retains considerable amounts of carbon on account of the strong affinity of manganese for carbon. Work at Tacony was stopped on account of a terrific explosion, which destroyed the plant. The then high price of aluminum made the cost of manganese too high, so the works were not rebuilt. Messrs. Green and Wahl worked along the lines of the earlier investigators, who carried on their experiments in crucibles heated in furnaces. The reaction, when once started, was often so violent as to blow the whole charge out of the crucible. The explosion at the Tacony Works was due, probably, to some violent reaction taking place in the reduction process.

By modifying the mode of operating, Dr. Hans Goldschmidt, of Essen, Germany, has taught us how to control the violence of the reaction. His important process will be discussed later on, and we will confine our attention for the present to the action of aluminum as a reducing agent pure and simple.

Taking, *e.g.*, *nickel*, — its melting-point lies at 1450° C.[2] In melting it down in a crucible, a superficial oxidation can hardly be prevented, and some of the nickelous oxide formed is taken up by the nickel and makes it brittle. Therefore, until about twenty-five years ago, most of the nickel in the market was in the form of small welded cubes. Nickelous oxide was mixed with sugar, starch, or a similar reducing agent, formed into cubes, dried, and brought in a closed vessel to a white heat, when the reduced metallic nickel particles readily welded together. Broken nickel is prepared in a similar manner. In 1876 Mr. Jos. Wharton, of Camden, New Jersey, exhibited at the Centennial Exposition of Philadelphia, nickel in the form of cast ingots, slabs, etc. He had added the necessary small amounts of magnesium

[1] Garrison. Transactions American Institute of Mining Engineers, 21, 887.
[2] Styffe. Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 1894, 340.

to the crucible-charge, which reduced the nickelous oxide, the magnesium being converted into magnesia. In the absence of nickelous oxide, it was an easy matter to melt and cast nickel. Today nickel anodes in the form of slabs are a regular article of commerce. Magnesium has to some extent been replaced by aluminum, which, according to the table, is more powerful.

In making *brass* in a crucible, the copper is first charged, covered with charcoal and melted down; then zinc, previously warmed, is added in small amounts at a time in order to prevent cooling. When the necessary quantity has been charged, the alloy is heated to the pouring temperature, which lies near the ignition point of zinc, and is thoroughly stirred. The charcoal cover prevents most of the oxidation, but not all of it. An addition of 0.05—0.10% aluminum counteracts all oxidation completely; the brass will flow more freely, and will be stronger and tougher, even if no aluminum whatever remains in the alloy.

The Roessler-Edelmann Process. A very interesting application of the reducing effect of aluminum has been made by Messrs. Roessler and Edelmann, of Frankfort s. M., Germany, in desilverizing argentiferous lead by means of zinc (Parkes Process). Here from 1 to 2% zinc is stirred into lead, melted down in a kettle having a capacity of thirty to sixty tons. A zinc-silver-lead alloy forms, which, having a higher melting-point and a lower specific gravity than the lead, solidifies before the lead and rises to the surface, when it can be skimmed off from surface, as is cream from milk, and worked up separately. In heating the lead (containing say 1% silver) to well above the melting-point of zinc (412° C.) and stirring in the zinc, a superficial oxidation of both lead and zinc cannot be prevented. The result is that the zinc-silver-lead alloy contains not more than 5% silver, because a large amount of unalloyed and partly oxidized lead is carried off with the skimming. By adding 0.5% aluminum to the zinc, Roessler-Edelmann obtained a zinc-silver-lead alloy with as much as 20% silver. This modification of the Parkes Process was in operation for several years at Lautenthal, Harz Mountains, Prussia, and at Hoboken, near Antwerp, Belgium.

Galvanizing.[1] A similar favorable effect of aluminum is seen in its use in galvanizing, *i. e.*, coating iron or steel sheets with zinc. Suitably prepared iron sheets are drawn through a bath of melted

[1] Richards. Aluminum-zinc. Jl. Franklin Instit., 1901, 151, 445.

zinc which slowly becomes oxidized, forms drosses, and loses its power to coat iron. By adding one pound of an alloy of zinc with 2% of aluminum to the zinc bath, this becomes more fluid; a given weight of zinc, thus charged, coats 20% more surface, the sheets are brighter, and keep their color better. The amount of aluminum added is only 0.001%, but it has this remarkable effect.

Aluminum and Iron. The effects that small amounts of aluminum have on the different forms of iron are of great importance. It was discovered by Wittenstrom in the 80's that, if 0.05 to 0.1% of aluminum was added to a charge of wrought iron heated to pastiness, the iron liquefied so that it could be poured. The castings, so-called Mitis castings, have similar properties to wrought iron, excepting that they lack the fibrous structure.

In making steel castings, an addition of 0.03 to 0.05% of aluminum has a very beneficial effect in reducing the small amounts of iron oxide that are formed, especially in pouring. The elimination of oxides makes the steel more tough, and by preventing the oxides from oxidizing some of the carbon of the steel, it hinders the evolution of carbon monoxide, which, stirring up the steel, causes the expulsion of occluded gases; it thus diminishes, if it does not prevent, the formation of blow-holes.

The effect of 0.01 to 0.05% of aluminum upon cast iron is to convert some of the combined carbon into graphitic carbon. It is mentioned here in connection with wrought iron and steel as the third form of industrial iron. A satisfactory explanation has so far not been offered.

In the examples given, the amounts of aluminum used are very small in comparison with the quantities of base metals that are to be cast; the reason being, of course, that only small percentages of oxides have to be reduced. When the oxides increase in amount, the aluminum required for reduction grows correspondingly. This leads to the use of aluminum as a reducing agent for refractory oxides.

Reduction of Refractory Oxides. Moissan,[1] in 1894, was the first to use an aluminum bath in an experimental way. He melted aluminum down in a crucible, added slowly the oxide to be reduced, and then formed an alloy of the reduced metal with aluminum. When cold, he separated the alloy from the slag, then melted it down again,

[1] Goldschmidt. Zeitschrift für Electrochemie, 4, 494.

and, working backward, added sufficient oxide to the melted alloy to oxidize the aluminum, and thus obtained the pure metal.

The Rossi Process. Mr. A. J. Rossi,[1] of New York City, who for a number of years has been working upon the industrial reduction of titaniferous iron ores, was the first to use an aluminum bath as a reducing agent for this class of ores in a commercial way. In his plant at Buffalo, New York, he uses an electrical furnace of the well-known Siemens type. It consists of a large block of agglomerated graphite with a central cavity to form the crucible; the block is encased in a wrought-iron shell, forming the cathode; the anode is a carbon block that can be raised and lowered. The crucible is charged with aluminum in waffles, or in the form of ingot or scrap, some scrap iron is added, the anode is lowered to make contact with the metal, the current is turned on, and the charge (titaniferous iron ore) shoveled in. The iron and aluminum soon become liquid, the aluminum reacts upon the titanium ore, fumes of alumina are given off, the temperature rises to such a degree that it becomes necessary to moderate the current; later, however, it has again to be increased to keep the slag and alloy molten. The contents of the furnace are now tapped and the furnace is recharged. In from one and one half to two hours a cake of alloy of 250 pounds is thus produced. The slag assays 80 — 85% Al_2O_3 and contains 90% of the aluminum charged. The alloys made show a range of Ti, 10 — 75%; C, 0.1 — 0.8%; S, — 0.015%. The slag forms an excellent abrasive material. The alloy is hard, scratches glass, and is silver white; when low in titanium, it has large, brilliant crystalline facets; when high in titanium, it is fine-grained and less lustrous; the higher the percentage of titanium the more brittle is the alloy.

An addition of 4 to 5% of ten to twelve per cent. alloy to cast iron gives this an increase of transverse strength of about 35%, and of tensile strength of 30 to 60%.

With steel, experiments have so far been confined to crucible steel with C, 0.4%; an addition of even small amounts decidedly increases the ductility.

There is no reason why this method of reduction by means of aluminum should not be extended to other ferro-metals, such as ferro-molybdenum, ferro-chrome, ferro-chrome-molybdenum. Mr. Rossi

[1] The Mineral Industry, ix, 715.

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has produced copper-titanium alloys with 5, 8, 10, and 15% Ti; the last one scratches glass easily.

The method of reducing refractory oxides by means of aluminum in an electrically heated furnace thus appears to have a good future before it, as long, of course, as the cost of aluminum, thirty-two cents per pound, is not too high, and the current sufficiently cheap.

The Hall Alumina Process.[1] Another interesting process in which aluminum figures as a reducing agent in an electrically heated furnace is that by Mr. C. M. Hall, of Niagara Falls, New York, the inventor of the Hall Aluminum Process, by means of which all aluminum of this country is produced. The raw material which furnishes the pure alumina for the electrolytic reduction of aluminum is bauxite with, say, Al_2O_3, 60%; Fe_2O_3, 18%; SiO_2, 2 to 3%; TiO_2, 3 to 4%; H_2O, 17%. This ore is usually mixed with sodium carbonate, heated to fritting in a reverberatory furnace, when sodium aluminate soluble in water is formed, while the other compounds remain insoluble. The fritted mass is leached with water; from the sodium aluminate solution, aluminum hydroxide is precipitated with carbon dioxide, and the original sodium carbonate regenerated. The aluminum hydroxide is filtered, washed, and calcined.

Mr. Hall now purifies the bauxite by a cheaper method (the Hall Alumina Process). The mineral is mixed with 8 to 10% of fifty-per-cent. ferro-aluminum, and the mixture then charged into an electrical furnace, similar in principle to the Siemens furnace, and held in fusion for about one and one half hours. The impurities, silica, ferric oxide, and titanic oxide, are reduced more or less completely to the native state, and, combining with the iron of the ferro-aluminum, sink to the bottom of the reduction vat. Silica and ferric oxide can be satisfactorily eliminated; less so, titanic oxide. The purified alumina differs, of course, from that obtained by the combined dry-and-wet method. It is grayish white, crystalline, has a specific gravity of 3.73 to 3.93; it resembles in structure a coarse-grained sandstone that is easily crushed, and often even friable between the fingers. It is partly soluble in hydrochloric acid and caustic alkalies, with liberation of methane and hydrogen; the former is probably due to an aluminum carbide, the latter to a partial reduction of Al_2O_3 to Al_3O_4, or Al_2O. The alumina furnished by this process is suited for making

[1] Townsend. Electric. World and Eng., July 6, 1901, p. 15.

a high grade of aluminum, and the process is, of course, a great deal cheaper than the usual combined dry-and-wet method. The alloy of iron, silicon, and titanium is, for the present at least, a waste product, unless researches similar to those of Mr. Rossi should procure a market for it.

The Goldschmidt Process.[1] The latest process is that of Dr. Hans Goldschmidt, of Essen, Germany. He uses aluminum as a reducing and a heating agent, and in many cases can manufacture from the resulting alumina a satisfactory abrasive material. This process has created quite a stir in the technical world, and has already an extensive literature. Even a new word, "aluminothermie" (aluminothermics), has been coined for it, in that it forms a new departure in reducing operations.

In this process, just as in the early experiments, aluminum in a more or less finely divided state is mixed with a metallic oxide and then charged into a crucible, which here is lined with magnesia. While the early experimenters heated the crucible in a furnace until the whole charge had been brought to the ignition point of aluminum, Goldschmidt found that it was only necessary to start the reaction at one point of the charge. The reason for this is that the heat liberated is sufficient for the reaction to go on without any external heating at all, when it has once been started. From the starting point, the heat works outward, and in a few minutes it has passed through the entire mass and causes the whole charge to react. In order to start the reaction, a fuse of very inflammable material is inserted into the

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[1] Goldschmidt. Ann. d. chemie, 1898, **301**, 19.
—— Verh. d. Vereins z. Bef. des Gewerbefleisses, 1899, 57; Jl. Iron and Steel Inst., 1899, II, 475.
—— Z. Verein Deutsch. Ing., **42**, 1019—1022; Jl. Iron and Steel Inst., 1898, II, 548.
—— Stahl und Eisen, 1898, 468; Jl. Iron and Steel Inst., 1898; II, 387; 1900, 567, 612; 1901, 23, 546, 560.
Lange. Jl. Iron and Steel Inst., 1900, II, 191.
Goldschmidt. Z. Electro-chemie, **7**, 935; Stahl und Eisen, 1901, 1155.
—— Z. Electro-chemie, **4**, 494 (Iron Age, 1898, October 6, p. 2).
—— Trans. Inst. Mining Eng., 1900, **19**, 411; Z. Angew. Chemie, 1900, No. 37, 919.
—— Z. Electro-chemie, 1899, **6**, 53.
—— Glück Auf, 1900, **36**, 466.
Archdeacon. Eng. Min. Jl., 70, 219.
Duboin & Gauthier. Compt. Rend., **129**, 217: Jl. Iron and Steel Inst., 1899, II, 476.
Clerc. Bulletin de l'Industrie Minérale, 1901, XV[3], 573.
Vanderheym. Bull de l'Ind. Min., 1901, XV, 627.

mixture and ignited. The fuse consists of a mixture of finely divided aluminum and barium peroxide formed into a paste; it is supplied with a magnesium ribbon, serving as a squib. The highly inflammable material, when ignited, produces locally the intense heat necessary to start the reaction.

The reduced metal will be free from aluminum so long as the crucible charge contains a slight excess of oxide over that which can be reduced by the aluminum added.[1]

Professor Kupelwieser,[2] of Leoben, Austria, has calculated the following heat-balance in reducing ferric oxide by means of aluminum and carbon:

TABLE.

THE REDUCTION OF Fe_2O_3 TO Fe BY Al AND BY C.

	Al.	C.
Compound produced	Al_2O_3	CO
Amount of reducing agent required to produce 1 kgr. of iron	0.484 kil.	0.321 kil.
Amount of heat produced by oxidation of the reducing agent	3,456 cal.	770 cal.
Heat required to reduce Fe_2O_3	1,796 cal.	1,796 cal.
Heat required for fusion of slag	548 cal.	....
Heat required for fusion of iron	362 cal.	....
Total heat required	2,706 cal.	1,796 cal.
Residual heat available	+ 750 cal.	— 1,026 cal.

In the aluminum-reduction there is available 750 calories; in the carbon-reduction there is a deficit of 1,026 calories.

Carbonless chromium and manganese produced by the Goldschmidt Process are of importance.[3] Pure chromium is almost incorrodible and has valuable electrical properties. Its main interest to the metallurgist lies in its use for making chrome steels, which so far contain

[1] The lecturer here carried out the experiment with ferric oxide and aluminum.

[2] Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 1899, 145; Jl. Iron and Steel Inst., 1899, II, 475.

[3] The lecturer presented specimens.

only 0.5 to 1% Cr. The ferrochromes (with 40 to 60% Cr) ordinarily used contain ten to twelve parts carbon to one part chromium, the chromium being present as a carbide. The addition of ferrochrome, therefore, incidentally raises the carbon content of the steel and makes it impossible to obtain chrome steels high in chrome and low in carbon. While the addition of the pure chrome to open-hearth or crucible steel is advocated, it seems probable that, instead of using expensive pure chromic oxide (Cr_2O_3), it will be found more convenient to use the cheaper mineral, pure chromite ($FeO.Cr_2O_3$) with 68% Cr_2O_3, which will be reduced by aluminum, and the carbonless ferrochrome then added to the charge.

It is claimed by Goldschmidt that in adding pure chromium to the steel-charge there is a smaller loss in chromium by slagging than when ferrochrome is used,[1] but this is contradicted by Blackwell.[2]

Manganese is of less interest to the steel smelter than to the non-ferrous metallurgist, in that the ferro-manganese (80% Mn) commonly used serves its purpose and is very much cheaper than the pure manganese of the Goldschmidt process. The costs are about as 1 : 10.

In making copper-manganese alloys the use of pure manganese is important, because in using ferro-manganese (80% Mn; 8 to 9% Fe) some iron always combines with the copper. Thus a cupro-manganese, with 25 to 30% manganese, retains 2.5 to 4% iron, which has a harmful effect.

In melting down nickel, manganese can take the place of magnesium or aluminum; in the manufacture of brasses and bronzes additions of $\frac{3}{4}$ to 3% of manganese show favorable effects. Manganese further is readily alloyed with zinc and tin; thus the alloys, 20% Mn and 80% Zn, and 50% Mn and 50% Sn, are used in the arts.

An alloy, 84% Cu, 12% Mn, 4% Ni (manganin), is used for electrical resistance coils; again, an alloy of 70% Mn and 30% Cr is alloyed with copper to form chrome-manganin, and so on.

Goldschmidt has produced with his process valuable alloys of iron and titanium with 20 to 25% Ti; of manganese and titanium with 30 to 35% Ti; of lead and barium with 30% Ba, showing thus also the reduction of some alkaline earth metals.

The slag produced in the process, resembling the purified alumina

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[1] Stahl und Eisen. 1901, 547.

[2] Electro-chemist and Metallurgist, I, 196.

of Hall, is a valuable substance, in that it is an artificial corundum, which next to diamond is the hardest mineral. The slag is used as an abrasive, as a crucible-lining, and may serve as raw material for producing aluminum by electrolysis.

In the Goldschmidt process, so far, the main object has been the reduction of a refractory metallic oxide, the heat generated serving to liquefy the reduced metal and the resulting slag. The process is being applied, also, simply as a heat producer, the heat being utilized for welding, soldering, annealing, etc., where it is not convenient to use other methods of heating. The aluminum in this case need not be pure; the cheapest source of oxygen will be ferric oxide. In order to retard the reaction and thus reduce the temperature, it is necessary to add a diluent to the charge, *e. g.*, silica, lime, or magnesia. This acid or basic flux combining with the Al_2O_3 will form a slag that surrounds the part to be heated. It is removed by tapping with a hammer when cold. The amount of reagent to be used and the degree of dilution desired will depend upon the melting-point, the size and conductivity of the metal or alloy to be heated. An excess of charge would melt the metal or alloy; an insufficient amount would not bring it up to the required temperature.

This method of heating has found very wide application, and may prove even more important than the reduction of refractory metallic oxides.[1]

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[1] Applications of the process made in welding pieces of wrought iron and steel, and in patching castings, were shown by means of illustrations thrown upon the screen.

A STUDY OF SELF-PURIFICATION IN THE SUDBURY RIVER.

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INTRODUCTORY.

FEW sanitary problems have been debated with less conclusive results than those relating to the extent of the self-purification which occurs in streams, and to the agencies involved. Twenty-five years ago almost implicit faith was placed in the efficiency of this process to render sewage-polluted water potable even in a comparatively short distance. For example, Chapter 80, Section 96, of the Public Statutes of Massachusetts, enacted in 1878, prohibited the discharge of polluting material into a stream or pond used as a source of water supply, only "within twenty miles above the point where such supply is taken." The changed opinion of the present day was expressed by Professor W. T. Sedgwick, in 1899, when he said of the Allegheny River at Pittsburgh: "Such is the peculiar character of the river and such the character of the watershed, that infection introduced at much more remote points than Oil City (113 miles above), may, in my opinion, be actively dangerous to the health of Pittsburgh."[1]

There is little question nowadays that self-purification in rivers is practically never so complete as to make such bodies of water safe sources of water supply without preliminary treatment. At the same time it is obvious that a very considerable, if only partial, purification does occur, both as regards the removal of organic material and the destruction of bacteria. The work of Professor E. O. Jordan on the bacterial purification of the sewage of Chicago in the great

[1] Report of the Filtration Commission of the city of Pittsburgh, Pennsylvania. 1899. P. 19.

drainage canal and the Illinois River, has drawn particular attention to this subject of late.[1, 2] In Jordan's earlier paper, as well as in one published four years ago by Hammerl,[3] are elaborate reviews of earlier work on the results of "self-purification" and its contributory causes. References to this literature will be found in the bibliographies contained in the papers referred to; the general results of the observations recorded showing that the problem is a complex one, and that each case must be considered *sui generis*. Schlatter, for example, found a complete self-purification in the Limmat, only 6 miles below Zurich; Frank could not detect the sewage bacteria of Berlin after an 8-mile passage through the Havelsee. Prausnitz recorded a removal of 50 per cent. of the germs contributed to the Isar by the city of Munich in a flow of 12 to 16 miles, occupying about 8 hours. On the other hand, Kruse and Lossen could not find evidence of any marked improvement in the Rhine, 16 miles, or about 5 hours' flow, below Cologne. Hammerl, using the presence of the colon bacillus, only, as an indicator, found that the sewage of the towns along the Mur disappeared at various distances, ranging from 2 miles up to 20. Hulwa recorded the complete chemical purification of the Oder by a flow of 20 miles below Breslau. Heider could detect the sewage of Vienna in the Danube at a point 24 miles below, by bacterial, but not by chemical, methods. In Jordan's work it appeared that while only one-half the bacteria introduced in the Chicago sewage was removed by a 29-mile flow through the drainage canal from Bridgeport to Lockport, at a rate of from $\frac{1}{2}$ to $\frac{9}{10}$ mile per hour, a flow of 27 miles between Lockport and Morris reduced the bacteria by 90 per cent., and a flow of 24 miles below Morris, at a rate of $\frac{1}{2}$ mile per hour, caused the complete disappearance of the excess of bacteria introduced at that place. Finally, at the opposite extreme to the favorable results of Schlatter and Frank, stand the observations of Durand-Claye, who found that a 60-mile flow of the Seine was required to remove all chemical evidence of the presence of the sewage of Paris. Altogether it is

[1] Jordan, E. O. Some Observations upon the Bacterial Self-Purification of Streams. Journal of Experimental Medicine, V, 1900, 271.

[2] Jordan, E. O. The Relative Abundance of Bacillus coli communis in River Water as an Index of the Self-Purification of Streams. Journal of Hygiene, I, 295.

[3] Hammerl, H. Ueber das Vorkommen des Bacterium coli im Flusswasser. Hygienische Rundschau, VII, 1897, 529.

clear that the rapidity and completeness of the purifying process varies very widely with local conditions.

The Sudbury River.

The Sudbury River, in the eastern part of Massachusetts, furnishes, in some respects, a particularly favorable opportunity for the study of self-purification. Of its total watershed of 164 square miles, the upper portion, including 94 square miles of steep and hilly country, is used as the source of part of the water supply for the Metropolitan District of Boston. The Legislative Act under which this water privilege was granted provided that 1,500,000 gallons of water per day should be allowed to flow past the lowest point at which water was taken by the city; and in dry weather the flow of the river immediately below scarcely exceeds this amount. From the reservoir of the Metropolitan Waterworks to the village of Saxonville, the stream is practically unpolluted, except at times of very heavy rain. At Saxonville it is dammed to furnish power for the Saxonville Mills, and from the mill grounds it flows off, heavily charged with manufacturing wastes. Measurements of these waste liquors, made by the Massachusetts State Board of Health in 1900 and 1901, showed their amount to be about 30,000 gallons per day, and this may now have increased somewhat on account of enlargements in the mills. The wastes, when studied by the Board, were made up of about 21,000 gallons of wool-scouring liquor, 7,000 gallons of dye liquor, and 2,000 gallons of yarn-washing liquor. The analyses made by the Board of Health[1] showed their composition to be as follows:

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[1] Report of the State Board of Health (of Mass.) upon the Sanitary Condition of the Sudbury and Concord Rivers and the meadows adjacent thereto. May, 1901.

AVERAGES OF ANALYSES OF WASTE LIQUORS FROM WOOL SCOURING, CLOTH WASHING, AND DYEING, AT SAXONVILLE.

[Parts per 1,000,000.]

	Residue on Evaporation.			Ammonia.				Chlorine.	Oxygen consumed.
					Albuminoid.				
	Total.	Loss on ignition.	Fixed.	Free.	Total.	In solution.	In suspension.		
No. 1 . .	14,880	7,180	7,700	102.7	67.6	—	—	—	1,200
No. 2 . .	16,960	11,030	5,930	61.0	120 7	58.8	61.9	255.6	1,362
No. 3 . .	20,830	17,550	3,280	3.0	154.8	87.0	67.8	279.0	2,810
No. 4 . .	3,410	2,580	830	0.5	13.0	—	—	—	498
No. 5 . .	26,220	12,310	13,910	5.6	101.0	12.0	89.0	350.0	1,780
No. 6 . .	3,370	810	2,560	9.6	23.6	22.6	1.0	204.0	102

NOTE: No. 1 is an average of samples collected November 16, 1900, of wool-scouring liquors. No. 2, average of all samples of wool-scouring liquors. No. 3, average from first bowl of yarn-washing liquor. No. 4, average from second bowl of yarn-washing liquor. No. 5, average of cloth-washing liquor. No. 6, sample of waste liquor from dyeing.

Besides the manufactural wastes from the mills, a certain small amount of domestic sewage probably enters the river from the village of Saxonville. Below the village, however, beyond the station marked 10 on the accompanying plan (Figure 1), the stream flows for 16 miles to the town of Concord without any appreciable additional pollution. For the first 3 miles below Saxonville it runs rather rapidly, in places perhaps at a rate above 2 miles per hour. Beyond Station 9 on the plan, the river enters the Wayland and Sudbury meadows, and for the rest of its course winds sluggishly along through a weedy channel with a speed of not over $\frac{1}{4}$ mile per hour. There are no dwellings, with the exception of half a dozen summer camps in the proximity of the river, in all this distance; and it is entered by only a few small tributary brooks.

We have, then, in the Sudbury River, during the dry season, a small stream polluted at a single point to an extent of about 2 per cent. of its total volume by a liquid three to five times as strong as ordinary city sewage. For 16 miles below this point no additional pollution enters, and (at times of low water) comparatively little dilution occurs. For most of this distance the flow is very sluggish, and

the conditions for self-purification decidedly favorable. The report of the Massachusetts State Board of Health, already quoted, contains analyses of samples taken from seven points between Saxonville and Concord on August 15, 1900, from eight points on August 29, 1900, and from five points on February 27, 1901. In general, these analyses showed a marked purification; and in commenting upon them the engineer of the Board noted that near the outlet of Hurd's Pond, 4 miles below the Saxonville dam, half the pollution as measured by free and albuminoid ammonia disappeared, and that at Canal Bridge, 7½ miles below the dam, practically all evidence of pollution was removed. No bacteriological analyses, and no determinations of dissolved oxygen, were made upon these samples. The object of the present investigation was to extend the study of the State Board of Health by making complete chemical and bacteriological analyses of a more extended series of samples taken at the time of minimum flow of the stream, when the conditions for the study of self-purification are most favorable.

All field-work and collection of samples has been done by Messrs. Winslow and Hansen: all chemical work by Mr. Woodman; and all bacteriological work by Mr. Winslow. The figures have been drawn by Mr. Hansen. For the conclusions the authors are alike responsible.

Collection of Samples.

The first set of samples, ten in number, were collected October 25, 1901, the first sample, at Concord, being taken at 11 o'clock A.M., and the last, above the Saxonville dam, about 8 P.M. The position of the stations is shown on the plan (Figure 1). Station 1 was about 16 miles below the dam and just above the first houses of the town of Concord; Station 2 was at the outlet, and Station 3 at the inlet, of Fairhaven Bay, the only considerable pond on this part of the stream; Stations 4 to 7 were at points 2 to 3 miles apart in the course of the stream through the meadows; no sample was taken at Station 8 on this first day; Stations 9 and 10 were at bridges, respectively 2.7 miles and 3,000 feet below the Saxonville dam; no sample was taken on this day at Station 11, 150 feet below the entrance of the raceway from the mill; Station 12 was in the mill-pond, just above the dam. One week later, November 1, a second set of samples was taken, covering all the twelve stations indicated on the chart, but

in the inverse order, beginning at Saxonville at 9 A.M. and ending at Concord at 5 P.M. The weather on both days was clear, except for a shower in the afternoon of November 1, beginning about 3 P.M.; and for several weeks previously there had been very little rain. The temperature of the water was taken on the second day and varied only between 11° and 12° C., except at Station 11, just below the mill, where it was 18°. It was not possible to make measurements either of the amount of water flowing in the river or of the velocity. As regards the latter point, however, it is certain that $\frac{1}{4}$ mile per hour would be an outside estimate of the speed below Station 8. At each station three samples were taken, one for bacteriological analysis, one for chemical analysis, and one for the determination of the dissolved oxygen; and each sample was collected in three portions, from each side and from the centre of the stream. Inspection at the time of taking the samples showed the existence of pollution evident to the eye above Station 6, but no farther down the river. At Station 11 the stream, which had almost all passed through the mill, was highly discolored with dye liquor and very offensive. At Station 10 the milky look had somewhat disappeared, but the water was obviously foul; and between this point and Station 9 the stream flowed swiftly over a bed of rocks largely overgrown with Leptomitus, or some other sewage fungus. Between Stations 9 and 7 the speed of the river slackened, and an opportunity was furnished for sedimentation. At Station 6 the last ocular evidence of contamination was noticed, consisting of a considerable amount of flocculent suspended material in the water.

Bacterial Analyses.

The analysis of the bacterial samples was begun on the evening of collection Gelatin plates were made in duplicate and kept at room temperature, and agar plates were made and incubated at 37° to give some idea of the proportion of thermophiles present. The agar plates were counted after 18 hours, the gelatin plates after 60 hours. Four or five portions of each sample were incubated in dextrose broth to determine the presence of *B. coli*. In the first set of samples portions of 1 c.c., $\frac{1}{10}$, $\frac{1}{100}$, and $\frac{1}{1000}$, and in the polluted portions of the river, of $\frac{1}{10000}$ c.c., were used. In the second set of samples, a definite portion was selected for each station, $\frac{1}{100}$ c.c. for Stations 10 and 11, $\frac{1}{10}$ for Stations 8 and 9, and 1 c.c. for the

other points, and five duplicate tubes were inoculated. From the tubes showing fermentation of dextrose, litmus-lactose-agar plates were made; and if red colonies appeared, three were fished from each plate and sub-cultures made. Only those organisms giving typical reactions in dextrose broth, milk, nitrate solution and peptone solution, in the gelatin stab and on the agar streak, were considered to be colon bacilli.

Chemical Analyses.

The methods of chemical analysis followed were in the main similar to those employed in the systematic examination of water supplies by the Massachusetts State Board of Health. They are quite fully described in published reports of the Board, and it will be necessary to mention specifically only a few minor points.

The chemical analysis was begun on the morning following the collection of the samples. A portion of the sample was filtered through washed Swedish filter paper, and the filtered water was used for the determination of residue on evaporation, oxygen consumed, and color. The albuminoid ammonia was determined on both the filtered and unfiltered water, thus giving the amount in solution and suspension.

Color was determined by comparison with natural water standards, and is expressed in terms of the standard ammonia solution. Nitrites were estimated by Ilosvay's modification of the Griess method after decolorization with milk of alumina. Oxygen consumed was determined by Kubel's hot acid method, adding the reagents cold and boiling for five minutes. The figures given for the chlorine represent the average of closely agreeing duplicate determinations. Oxygen dissolved was determined by Winkler's method on special samples collected at the same time as the samples for the main analysis.

TABULATION OF RESULTS.—TABLE I.

CHEMICAL ANALYSES.—SERIES I, OCTOBER 25. (Figures 2 to 6.)

(Parts in 1,000,000.)

Station.	Date of Collection.	Date of Examination.	Physical. Color.	Physical. Turbidity.	Physical. Sediment.	Physical. Odor. Cold.	Physical. Odor. Hot.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on ignition.	Residue on Evaporation. Fixed.	Nitrogen as Alb. ammonia. Total.	Nitrogen as Alb. ammonia. Sol'n.	Nitrogen as Alb. ammonia. Susp.	Nitrogen as Free ammonia.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Oxygen consumed.	Hardness.	Chlorine.	Oxygen. Per cent. saturation.
	1901.	1901.																		
1	Oct. 25	Oct. 26	.95	V. sl.	V. sl.	Dist. veg.	Dist. veg.	63.5	22.5	41.0	.240	.214	.026	.020	.003	.070	9.24	18.2	5.55	68.34
2	"	"	.93	"	"	Dist. veg. and f. musty	" "	64.0	24.0	40.0	.262	.218	.044	.032	.002	.080	9.41	16.9	5.35	65.40
3	"	"	.93	"	"	" "	" "	62.0	21.0	41.0	.224	.176	.048	.044	.002	.090	9.13	18.2	5.24	61.91
4	"	"	.70	"	"	" "	" "	66.5	22.5	44.0	.230	.194	.036	.034	.004	.090	8.23	18.2	5.60	61.24
5	"	"	.75	"	"	Dist. veg. and musty	" "	61.0	20.0	41.0	.232	.198	.034	.034	.003	.050	8.15	18.2	5.30	60.53
6	"	"	.70	"	Sl.	" "	" "	86.0	24.5	61.5	.224	.186	.038	.018	.002	.070	7.78	22.1	5.37	64.21
7	"	"	.95	Sl.	"	Veg. and unpleas.	Veg. and unpleas.	65.0	24.0	41.0	.258	.228	.030	.034	.004	.100	8.83	15.6	4.60	54.64
8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9	"	"	.95 turbid	Dist. and woolly threads	Sl. to consid. brown	"	Dist. veg.	63.5	23.5	40.0	.292	.214	.078	.028	.003	.110	9.51	15.6	5.08	56.40
10	"	"	.97 turbid	"	Cons. floc. and woolly	"	"	65.0	28.5	36.5	.338	.226	.112	.032	.005	.120	10.19	14.3	4.70	60.74
11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	"	"	.93	V. sl.	V. sl.	Dist. veg. and f. musty	"	51.5	22.0	29.5	.236	.184	.052	.014	.002	.100	8.76	12.7	3.70	64.49

(Parts in 1,000,000.)

Station.	Date of Collection.	Date of Examination.	Physical. Color.	Physical. Turbidity.	Physical. Sediment.	Physical. Odor. Cold.	Physical. Odor. Hot.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on ignition.	Residue on Evaporation. Fixed.	Nitrogen as Alb. ammonia. Total.	Nitrogen as Alb. ammonia. Sol'n.	Nitrogen as Alb. ammonia. Susp.	Nitrogen as Free ammonia.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Oxygen consumed.	Hardness.	Chlorine.	Oxygen. Per cent. saturation.
	1901.	1901.																		
1	Nov. 1	Nov. 2	.60	None	V. sl.	F. veg.	Dist. veg.	63.0	23.5	39.5	.186	.160	.026	.030	.002	.140	7.06	18.2	4.65	71.95
2	"	"	.55	"	"	"	" "	62.5	23.0	39.5	.176	.160	.016	.044	.002	.120	7.14	16.9	4.65	67.02
3	"	"	.45	V. sl.	Sl.	Dist. veg.	" "	61.5	21.0	40.5	.182	.156	.026	.054	.004	.180	6.16	18.2	5.19	65.80
4	"	"	.50	"	V. sl.	" "	" " and f. grassy	65.0	22.0	43.0	.198	.186	.012	.036	.003	.180	6.90	18.2	5.19	62.30
5	"	"	.50	"	Sl.	" "	Dist. veg.	65.0	21.5	43.5	.200	.164	.036	.018	.003	.130	6.75	18.2	5.11	59.55
6	"	"	.48	Sl.	Sl. to cons.	" "	" "	65.0	20.5	44.5	.192	.146	.046	.026	.004	.180	6.61	19.5	5.44	63.70
7	"	"	.48	V. sl.	Sl.	" "	" "	56.0	18.5	37.5	.208	.180	.028	.032	.004	.120	7.50	18.2	4.65	56.58
8	"	"	.65	Sl.	"	" " and f. musty	" "	65.0	23.5	41.5	.204	.180	.024	.022	.004	.170	7.53	19.5	4.95	49.63
9	"	"	.70 turbid	Dec. floc.	Sl. to cons.	Dist. veg. and musty	" " and f. unpleas.	87.0	30.0	57.0	.344	.290	.054	.004	.011	.150	8.70	23.4	7.43	26.02
10	"	"	.55	Dist. floc.	Sl.	Dist. veg. and unpleas.	Dist. veg.	76.0	25.5	50.5	.304	.194	.110	.002	.010	.270	7.38	24.7	7.08	48.39
11	"	"	.95-1.00	Dist. to Dec.	Sl. to cons.	" "	" "	92.0	34.0	58.0	.572	.358	.214	.012	.002	.070	11.63	14.3	4.85	33.73
12	"	"	.93	V. sl.	Sl.	Dist. veg. and f. musty	" "	49.5	19.5	30.0	.164	.152	.012	.022	.001	.120	8.25	13.5	3.20	74.18

[illegible]

[illegible]	[illegible]		[illegible]	
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE IV.

PRESENCE OF BACILLUS COLI.

Station.	Series I, Oct. 25.			Series II, Nov. 1.					
	In 1 c.c.	In $\frac{1}{10}$ c.c.	In $\frac{1}{100}$ c.c.	In					
1	—	—	—	1 c.c.	—	—	—	—	—
2	—	—	—	1 c.c.	—	+	—	—	—
3	—	—	—	1 c.c.	—	—	—	—	—
4	—	—	—	1 c.c.	+	—	+	—	—
5	—	+	—	1 c.c.	+	—	+	+	+
6	+	—	—	1 c.c.	+	+	+	+	+
7	+	—	—	1 c.c.	+	—	+	+	
8				$\frac{1}{10}$ c.c.	+	+	+	—	
9	+	—	—	$\frac{1}{10}$ c.c.	+	—	+	+	—
10	+	—	+	$\frac{1}{100}$ c.c.	—	—	—	—	—
11				$\frac{1}{100}$ c.c.	+	+	+	—	+
12	—	—	—	1 c.c.	—	—	—	—	—

Conclusions.

The first thing which attracts attention is the fact that, in a general way, the pollution was not so great with the first set of samples collected on October 25 as with the set of November 1; it is true, however, that this apparent difference is partly due to the absence, in the first set, of a sample from Station 11, where the pollution would naturally be expected to be at its maximum. Another striking feature is the absence of the factor which usually proves the most valuable indicator of pollution, the free ammonia. This is no doubt due to the peculiar nature of the contaminating material, one entirely different from house sewage, in that it decays only slowly. For this reason this particular case is in some ways better, in some ways worse, than might have been desired. On one hand, a factor usually relied upon for convicting evidence is removed; on the other, the changes taking place in such material are probably more prolonged than those which affect domestic sewage, and are therefore more readily followed and studied. Further, the Saxonville sewage did not very notably increase the chlorine content of the water, the nitrogen present as nitrites, or the organic matter oxidized by potassium permanganate. The diagrams plotted to show the results of these features of the chemical analysis furnish very little information (Figures 2 to 6). The residue on evaporation, the nitrogen present as albuminoid ammonia and nitrates, and the dissolved oxygen are, on the other hand, significant.

The albuminoid ammonia curves (Figure 3) show a rise on both days, with a maximum at the station nearest the mill. From this point the amount of albuminoid ammonia decreases, gradually, the last point at which an excess is noted being Station 7. The "suspended" albuminoid ammonia drops still more quickly, and shows a more regular change, a fact due, no doubt, to the direct and constant influence of sedimentation, assisted possibly by the filtering effect of weeds or sedges. The residue and hardness (Figures 2 and 5) show a somewhat similar relation, with the important difference that the fixed residue and hardness do not return quite to the normal in the whole length of the river, being perhaps added to by leakage of ground water along the course of the river. The very marked excess on the second day, however, disappeared below Station 8. The peculiar break in the residue curve at Station 6, on the first

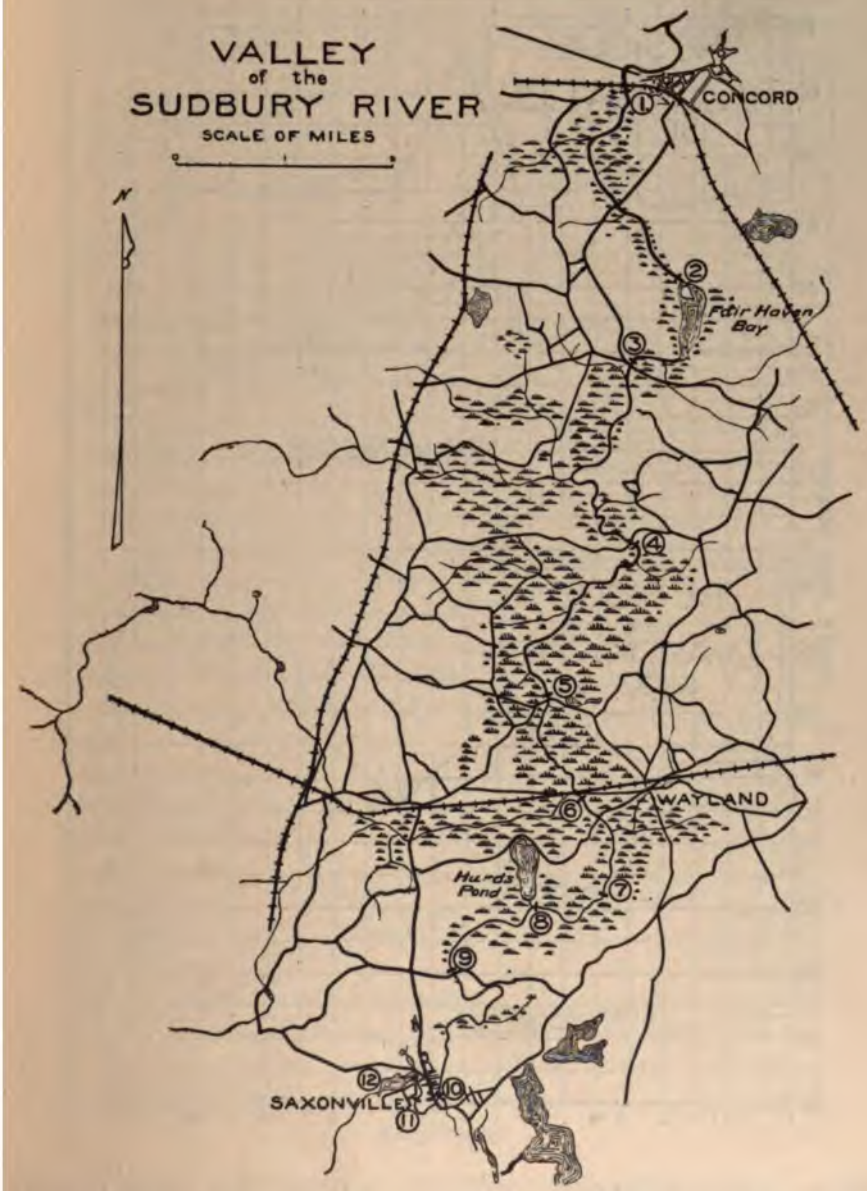

FIG. 1.—MAP OF THE SUDBURY RIVER BETWEEN SAXONVILLE AND CONCORD, SHOWING THE LOCATION OF THE STATIONS.

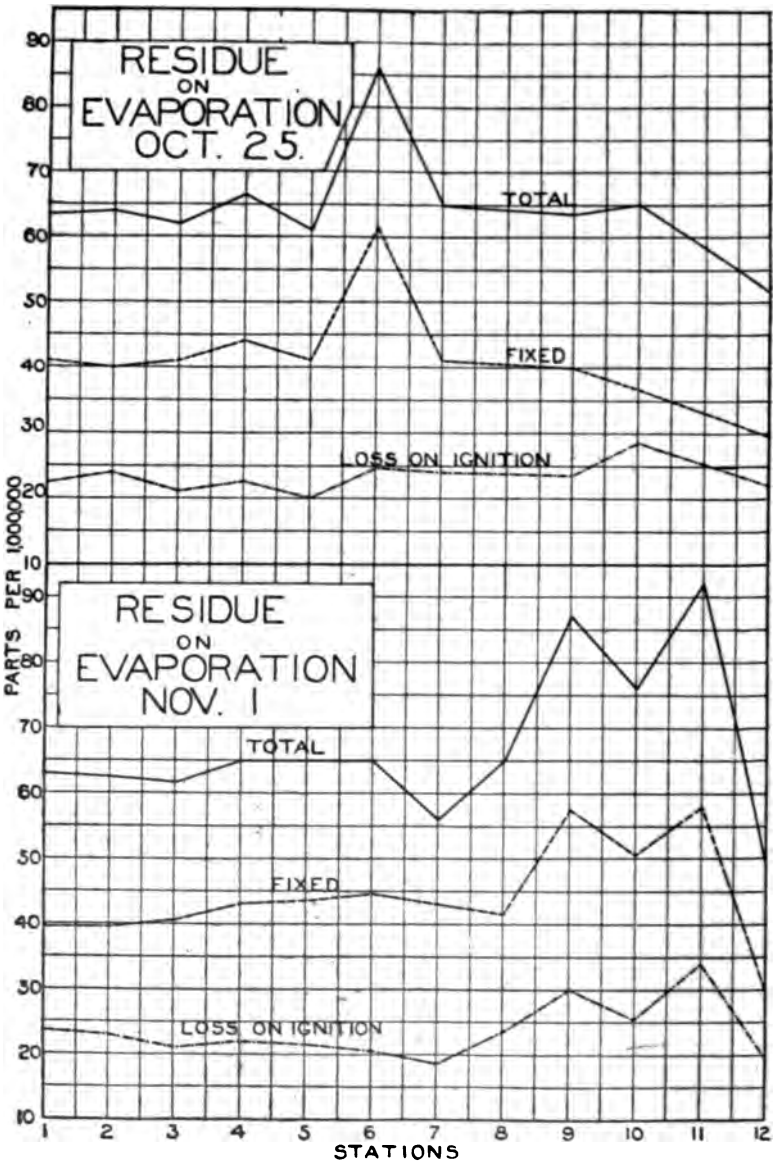

FIG. 2.—CHANGES IN CHEMICAL CONSTITUENTS IN PASSING FROM STATION 12, ABOVE SAXONVILLE MILLS, TO STATION 1, AT CONCORD. (To be read from right to left.)

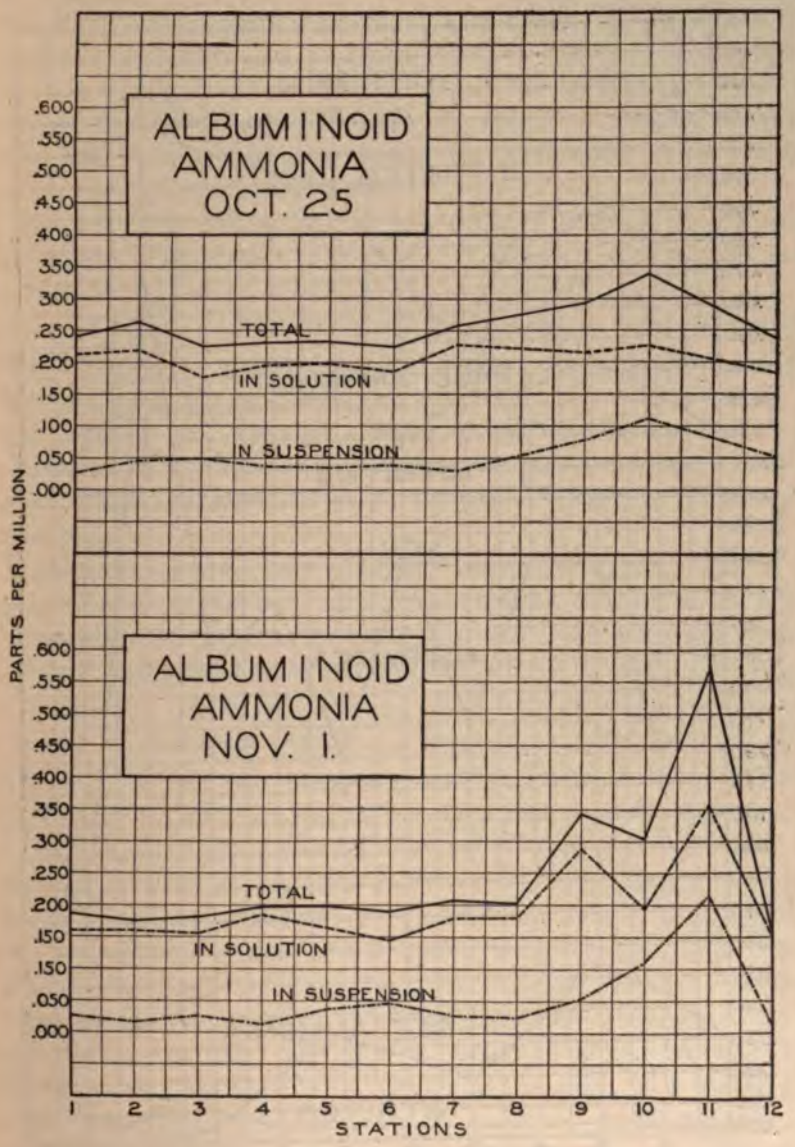

FIG. 3.—CHANGES IN CHEMICAL CONSTITUENTS IN PASSING FROM STATION 12, ABOVE SAXONVILLE MILLS, TO STATION 1, AT CONCORD. (To be read from right to left.)

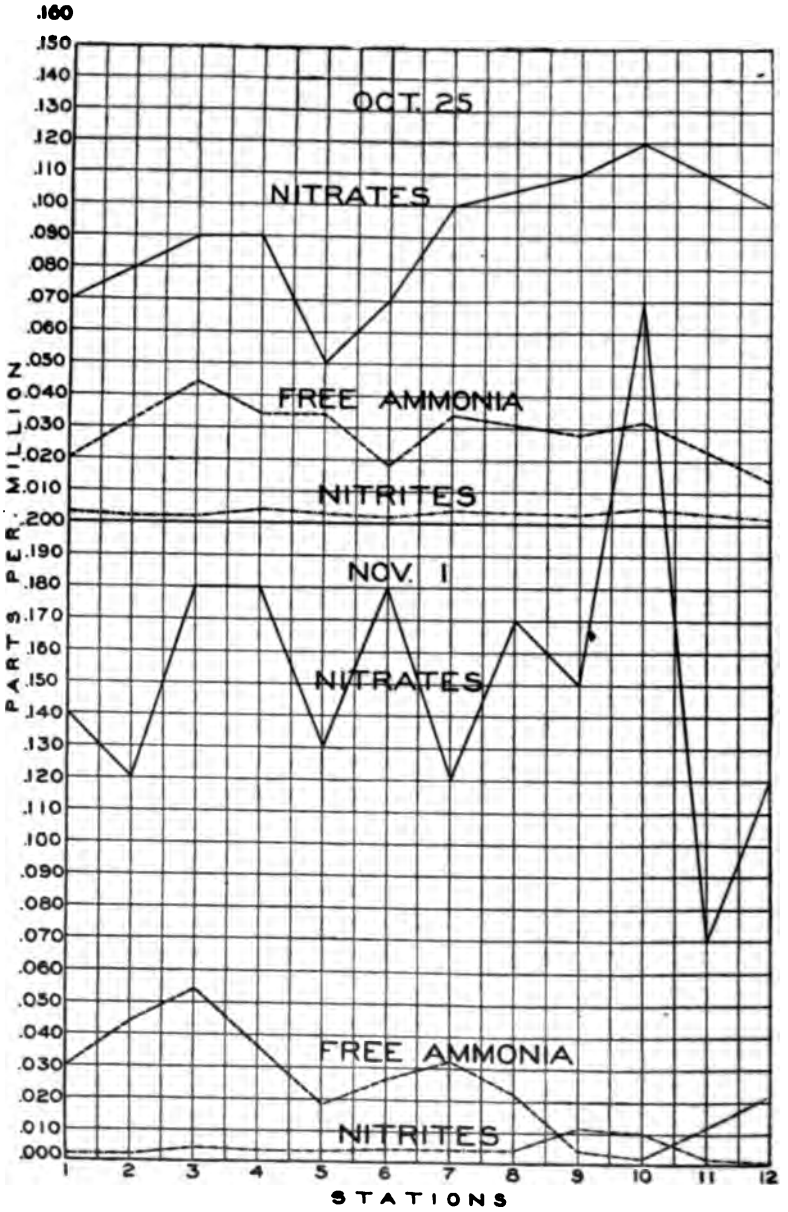

FIG. 4.—CHANGES IN CHEMICAL CONSTITUENTS IN PASSING FROM STATION 12, ABOVE SAXONVILLE MILLS, TO STATION 1, AT CONCORD. (To be read from right to left.)

day, may have been due to the admixture of a harder and clearer water from underground springs at this point. It will be noticed that it is accompanied by an increase in hardness and a decrease in color and oxygen consumed (Figure 5). The same thing is not observed in the second set. Possibly the sample at Station 6, on the second day, was not taken at exactly the same point as on the first day, but at a point a little above.

The irregular fluctuations of the nitrates (Figure 4) are somewhat hard to understand. The rise at Station 10, with a subsequent decrease, is evident in both curves; and the fall at Station 11, on the second day, is interesting as suggesting a reduction of the nitrates normally present in the water. The dissolved oxygen (Figure 6) shows the pollution and self-purification very clearly. A strong decrease on November 1, and a slight decrease on October 25, are followed by a gradual rise, reaching the normal between Stations 6 and 7; this region seems to be the crucial point of the chemical purification.

The results of the bacteriological analysis (Figures 7 and 8) are very instructive. The total number of bacteria present in the water, as determined by growth on gelatin at 20°, rose from one or two hundred to many thousand; a comparison of the figures for Stations 9 and 10 on the two dates showing, as do the chemical results, that the pollution was much greater on November 1 than on October 25. The fact that on both occasions Station 10 gave lower numbers than Station 9, may be due to the fact that a small spring feeds the river at the former place. The pollution, as measured by the bacteria, is evident as far down as Station 3, considerably below the point at which the chemical purification appears to be complete. The thermophiles, as measured by the growth on agar at 37°, show a similar enormous increase, but their disappearance in the river is more rapid, the numbers reaching about their normal values at Station 6, on the first day, and at Station 8 on the second. The examination of the samples for the colon bacillus, on the first day, showed that organism to be present in $\frac{1}{100}$ c.c. at Station 10, and in 1 c.c. below that point to Station 6. At Station 5 it happened that it was isolated from $\frac{1}{10}$ c.c., and not from the whole cubic centimeter examined; below that point it was not found. On the second day a certain dilution was chosen, and five duplicate samples examined. Bacillus coli was present four times out of five in $\frac{1}{100}$ c.c.,

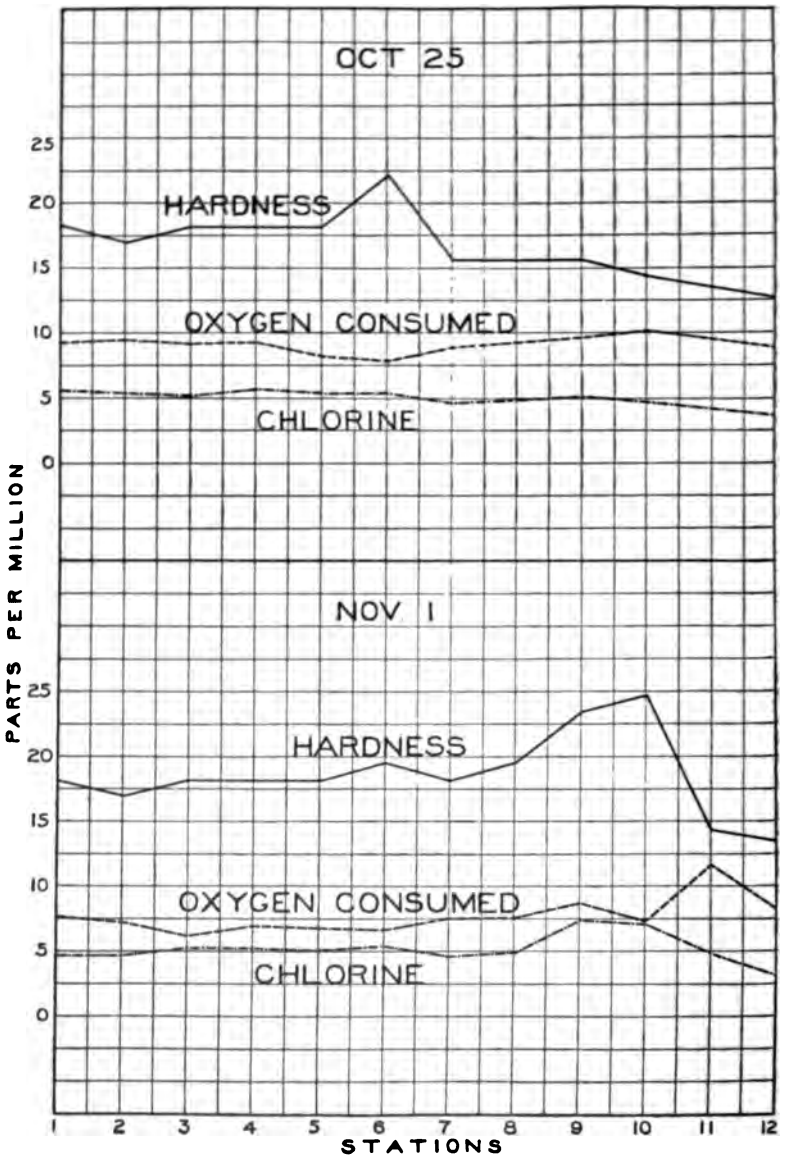

FIG. 5.—CHANGES IN CHEMICAL CONSTITUENTS IN PASSING FROM STATION 12, ABOVE SAXONVILLE MILLS, TO STATION 1, AT CONCORD. (To be read from right to left.)

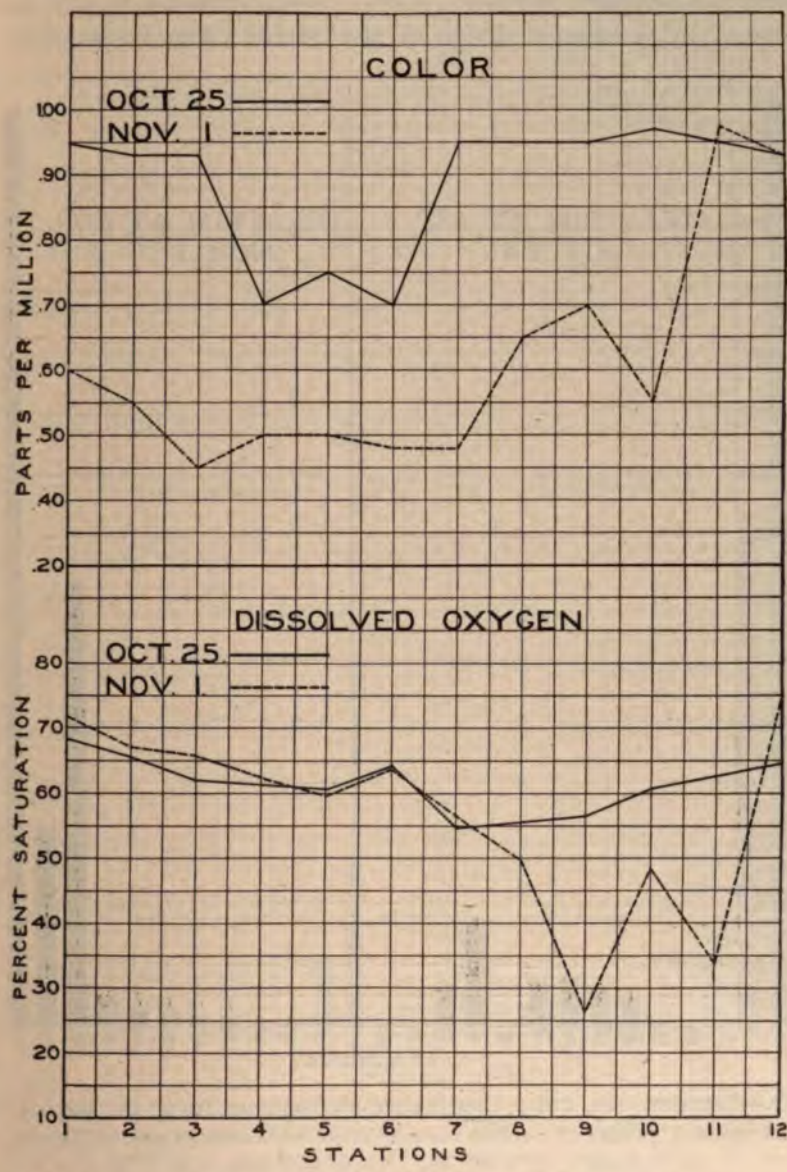

FIG. 6.—CHANGES IN CHEMICAL CONSTITUENTS IN PASSING FROM STATION 12, ABOVE SAXONVILLE MILLS, TO STATION 1, AT CONCORD. (To be read from right to left.)

at Station 11, but not at all in that quantity at Station 10. It was found in a majority of cases in $\frac{1}{10}$ c.c. at Stations 8 and 9. It appeared in a large majority of the single cubic centimeters ex-

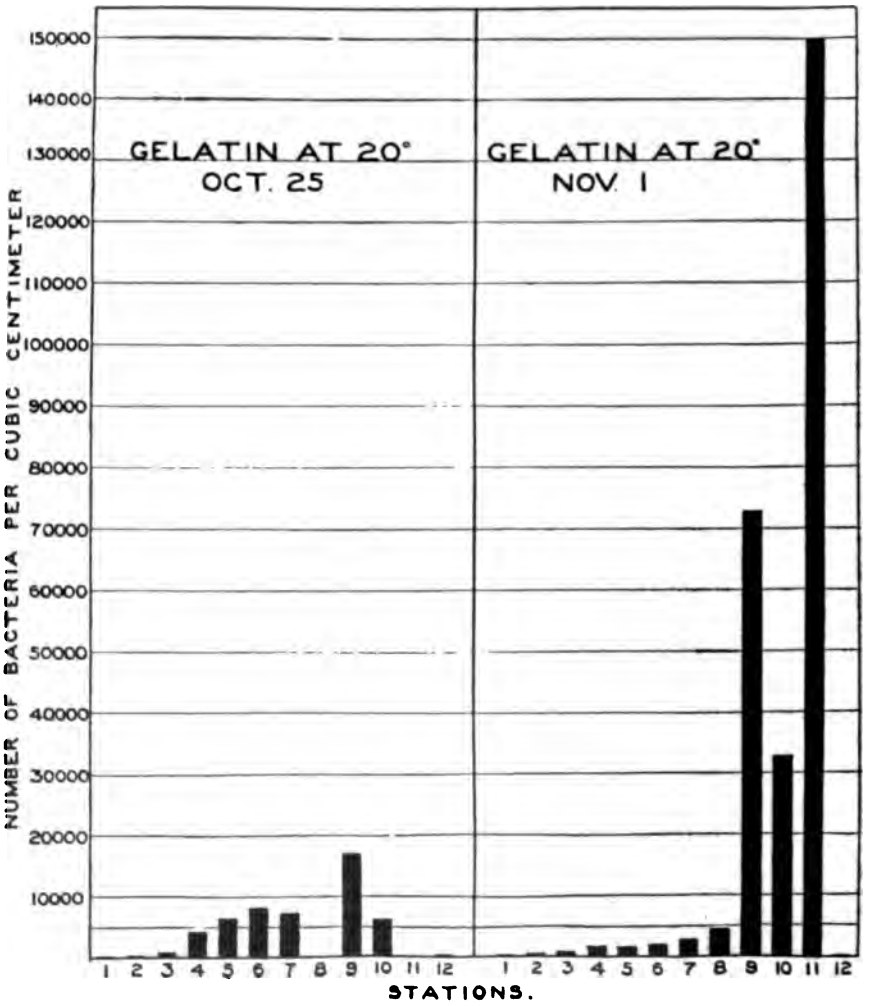

FIG. 7.—BACTERIA PER CUBIC CENTIMETER ON GELATIN AT 20° C. CHANGES IN BACTERIAL CONTENT IN PASSING FROM STATION 12, ABOVE SAXONVILLE MILLS, TO STATION 1, AT CONCORD. (To be read from right to left.)

amined from Stations 5, 6, and 7; in two cases out of five at Station 4, and in one case out of five at Station 2; not at all at Stations 1 and 3.

To summarize: The sewage of the Saxonville Mills, on the days observed, introduced into the Sudbury River a considerable amount of nitrogenous matter in the form of albuminoid ammonia, a consider-

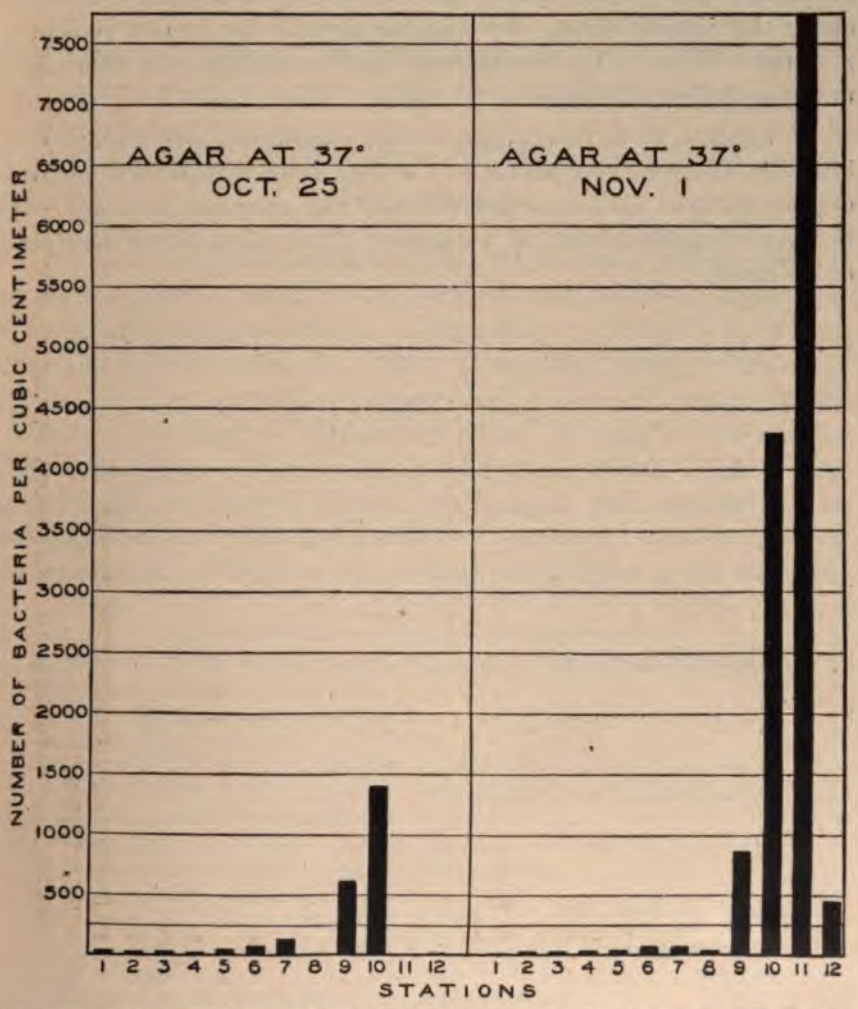

FIG. 8.— BACTERIA PER CUBIC CENTIMETER ON AGAR AT 37° C. CHANGES IN BACTERIAL CONTENT IN PASSING FROM STATION 12, ABOVE SAXONVILLE MILLS, TO STATION 1, AT CONCORD. (To be read from right to left.)

able amount of mineral matter appearing mainly as fixed residue and hardness, and great numbers of bacteria, many of them thermophiles with some intestinal bacilli. During the 6 miles between

Stations 11 and 7, organic pollution decreased and practically disappeared, at first rapidly, later more gradually. The thermophilous bacteria were removed during the same period. The total number of bacteria present was also greatly reduced, but remained distinctly above the normal during the sluggish flow of the stream to Station 4, 4 miles below. The colon bacillus also persisted in appreciable numbers down to Station 4.

It appears, then, that under certain conditions bacteria, and even intestinal bacteria, may persist in a stream after self-purification from organic material has been effected; and that they may be found, even in a very sluggish stream, at a distance of 10 miles below their point of entrance.

ON THE PHYSICAL PROPERTIES OF GELATIN, WITH REFERENCE TO ITS USE IN CULTURE MEDIA.

By GEORGE C. WHIPPLE.

Introductory.

It is a fact only too well known that "sterilized nutrient gelatin," as now prepared for use in bacteriological work, is a most unsatisfactory medium; and especially is it unsatisfactory for the quantitative determination of bacteria in water. If any illustration of this were needed, none better could be found than the recent report of the Committee on Standard Methods of Water Analysis of the Section of Bacteriology and Chemistry of the American Public Health Association.[1] In its Second Report of Progress this committee had recommended the following method of preparing nutrient gelatin, and by vote of the Section this method was adopted as the standard.

Standard Method for Making Nutrient Gelatin.

1. Infuse 500 g. lean meat 24 hours with 1,000 c.c. of distilled water in refrigerator.
2. Make up any loss by evaporation.
3. Strain infusion through cotton flannel.
4. Weigh filtered infusion.
5. Add 1 per cent. Witte's pepton and 10 per cent. Gold Label sheet gelatin.
6. Warm on water bath, stirring until pepton and gelatin are dissolved, and not allowing the temperature to rise above 60° C.
7. Neutralize.
8. Heat over boiling water (or steam) bath 30 minutes.
9. Restore loss by evaporation.
10. Titrate, after boiling one minute to expel carbonic acid.
11. Adjust reaction to + 1.0 per cent. by adding normal hydrochloric acid or sodium hydrate as required.
12. Boil two minutes over free flame, constantly stirring.
13. Make up loss by evaporation.
14. Filter through absorbent cotton and cotton flannel, passing the filtrate through the filter until clear.
15. Titrate and record the final reaction.
16. Tube, using 5 c.c. in each tube.

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[1] Advance Notes from the Third Report of Progress. Printed for the use of the Members of the Section.

17. Sterilize 15 minutes in the autoclav at 110°, or for 30 minutes in streaming steam on three successive days.

18. Store in the ice-chest in a moist atmosphere, to prevent evaporation.

In order to test the value of these directions in obtaining a medium of uniform quality and one which would give uniform results, the committee sent invitations to various bacteriologists, asking them to submit samples for comparative tests. Eighteen such samples were received. These were tested as to their reaction, melting-point, specific gravity, etc., and their relative value for determining the number of bacteria in a sample of water. The results of these tests are given in the following table:

TABLE I.

Sample number.	Sterilization.		Reported reaction.	Color: L = light; D = dark; V = very.	Specific gravity.	Melting-point. (Cent.)	Observed reaction.	Number of bacteria per c.c.	Per cent. of plates which were partially liquefied.	Per cent. of plates which were wholly liquefied.
	Temperature. (Cent.)	Time. (Minutes.)								
2	100	3 × 30	1.00	L	1.0324	33.0	1.63	125	0	0
1	115	10	1.00	L	1.0334	31.4	1.05	124	0	0
11	110	15	0.80	D	1.0265	27.1	1.17	112	0	0
7	113	20	1.00	L	1.0142	24.8	1.32	110	60	0
8	113	20	1.00	L	1.0208	27.1	1.12	108	0	0
3	110	15	1.00	L	1.0295	31.4	1.05	101	0	0
5	100	3 × 30	1.00	D	1.0250	21.5	1.53	98	20	0
12	100	3 × 30	*	L	1.0346	26.2	1.88	87	0	0
16	100	4 × 30	1.00	V L	1.0300	24.8	0.56	81	0	0
4	100	3 × —	1.00	D	1.0298	23.8	0.95	80	—	40
14	100	4 × 15	0.95	V L	1.0310	26.2	1.98	78	0	0
17	100	3 × 30	1.45	L	1.0344	23.8	1.52	72	60	0
10	110	2 × 15	1.10	D	1.0308	24.8	1.13	55	—	40
13	—	—	—	V L	1.0289	23.8	1.32	44	40	60
9	110	15	1.20	V D	1.0353	23.8	—1.70†	29	100	0
6	100	3 × 20	0.78	D	—	24.8	0.52	Liq.	—	100
15	—	—	1.00	D	1.0247	23.0	1.93	Liq.	—	100
18	100	3 × 15	1.10	L	1.0362	22.5	1.35	Liq.	—	100

* Reported as "too acid." † Probably abnormal.

It appeared from this comparison that the different media varied greatly in melting-point, in reaction, etc., and that their different physical and chemical qualities affected their value for quantitative work to such an extent that, when used to determine the number of bacteria in Brooklyn tap-water, the maximum number obtained was more than four times the minimum number. It appeared, moreover, that the melting-point of the gelatin, or the temperature at which it became soft, had the greatest effect upon the bacterial count. Thus, the average number of bacteria found upon the gelatins which had melting-points above 25° C. was 105 per c.c., while the average number found upon the gelatins which melted below 25° C. was 71 per c.c. This seemed to be due to the more rapid spreading of the liquefying colonies in the softer gelatins, with consequent ob-

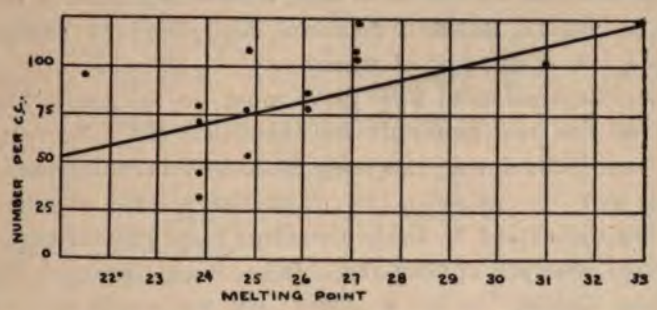

FIG. 1. — DIAGRAM SHOWING THE RELATION BETWEEN THE MELTING-POINT OF GELATIN AND THE BACTERIAL COUNT ON BROOKLYN WATER.

scuring of the smaller colonies. The general tendency for the firmer gelatins to give higher bacterial counts is shown in Figure 1. The unsatisfactory results shown by this comparison led the writer to undertake the present investigation.

NATURE OF GELATIN.

Gelatin is a substance of uncertain and varying composition obtained from the nitrogenous portions of bones, hides, connective tissues, etc. The collagen when boiled is changed to gelatin, which consists chiefly of glutin, derived from the skin and bones, with perhaps traces of chondrin, derived from the cartilage. Glue is practically impure gelatin plus a certain amount of some antiseptic and of some substance designed to increase its power of adhesion. There

are two principal kinds of gelatin — bone gelatin and hide gelatin. There is also isinglass, made from the bladders of sturgeon.

The general process of manufacture of hide gelatin is as follows:

The hide scraps are first macerated and subjected to the action of a solution of lime or caustic soda in pits for two or three weeks. This dissolves most of the blood and saponifies the fats. The excess of lime or soda is then largely removed by washing and the solution steamed to dissolve the gelatin, but an excess of heat is avoided. Sulphurous acid is used to bleach the gelatin. When of sufficient strength, the gelatin is allowed to harden in molds or on slabs, and is ultimately dried in sheets on wire nets. Bone gelatin is made in a somewhat similar manner. The bones are crushed, boiled, treated with hydrochloric acid, and the gelatin is ultimately dissolved as before, washed, bleached, and dried in sheets. The process requires a number of weeks.

When it is considered how great must be the variations in the character of the raw materials and how difficult it is to maintain constant conditions during the long process of manufacture, it is not surprising that the gelatins put upon the market should vary in quality; but the extent of these variations is far greater than bacteriologists have generally appreciated. It has been customary to specify "Gold Label Gelatin" as the standard; but practically this is of little value as a definition of quality. Some manufacturers make several grades of gold-label gelatin, and what is of even greater importance, the same brand of gelatin of any one dealer is not constant. It is seldom that two batches of gelatin are exactly alike both in their chemical and physical properties. When it is remembered how susceptible bacteria are to slight changes in environment, it is not to be wondered at that a culture medium which contains 10 per cent. of such a variable substance should at times give erratic results.

Gelatin is put upon the market in a variety of forms — thin sheets, thick sheets, broken sheets, shreds, granulated, and powdered. The sheet gelatin is almost invariably used by bacteriologists. The following is a list of the gelatins used in the experiments described beyond:

TABLE II. — LIST OF GELATINS USED IN THE EXPERIMENTS.

No.	Manufacturer.	Brand.	Obtained from.	Form.	Size of sheets. (Inches.)	No. of sheets to the pound.	Color.
1	....	"Gold Label"	Bausch & Lomb	Sheets	$3\frac{1}{8} \times 8\frac{1}{8}$	240	Light
2*	Heinrich	Hard Emulsion No. 9132	Paul Putmann	"	$3\frac{1}{4} \times 8\frac{1}{4}$	190	"
3	Compte Fils	"Gold Label"	Hoagland Laboratory	"	$2\frac{3}{4} \times 9$	135	"
4*	Nelson, Dale & Co.	Sheet Gelatin No. 3	Anthony & Co.	"	$3\frac{1}{4} \times 10$	28	Brown
5	Heinrich	"Gold Label"	Paul Putmann	"	3×9	290	Light
6	Compte Fils	"Gold Label"	Hibbert W. Hill	"	$2\frac{3}{4} \times 9$	135	"
7*	Cooper	A. A. Ex. Crescent	Factory	Broken sheets	..	.	Sl. dark
8*	Cooper	Crescent No. 1	"	"	..	..	Light
9	Coignet	Super Extra	Alfred Hodge & Co.	Sheets	3×9	16	Light yellow
10	....	Isinglass Russian	Eimer & Amend	Irregular sheets	..	..	Light
11	....	No. 1 Washed	....	..	..	..	"
12	....	Pure gelatin (prep.)		Amorphous	..	..	White
13*	Heinrich	Emulsion No. 1295	....	"	$3\frac{1}{4} \times 8\frac{1}{4}$	190	Light
14	Dentelle	Silver Label	Zinkeisen & Co.	Sheets	3×9	140	"
15	"	Neutral Gold Label	"	"	$3\frac{1}{4} \times 9\frac{1}{8}$	205	"

* Nos. 7 and 8 were glues rather than gelatins, and were not intended for bacteriological work. This fact should be noted in connection with Tables 14, 15 and 16, and with Plates XIII and XIV. Nos. 2. 4 and 13 were prepared especially for photographic purposes.

PHYSICAL PROPERTIES.

The physical properties of gelatin solutions may be described under the headings: *viscosity*, *spissitude*, and *melting-point*.

VISCOSITY.

When commercial gelatin is steeped in water it absorbs from five to ten times its weight of water, or enough to dissolve it at 30° C. In hot water gelatin solutions have a comparatively low viscosity, but as the temperature is lowered a "gelatinizing" process occurs, which increases the viscosity until the mass becomes a semi-solid.

The viscosity of gelatin solutions may be readily determined by

Tagliabue's viscosimeter,[1] designed to measure the viscosity of lubricating oils. This consists of a chamber which holds about 70 c.c., and which has at the bottom a standard aperture, controlled by a stop-cock. Through this the contents may be let out into a glass cylinder which holds 50 c.c., while the time required to fill the cylinder is determined with a stop-watch. The upper chamber is

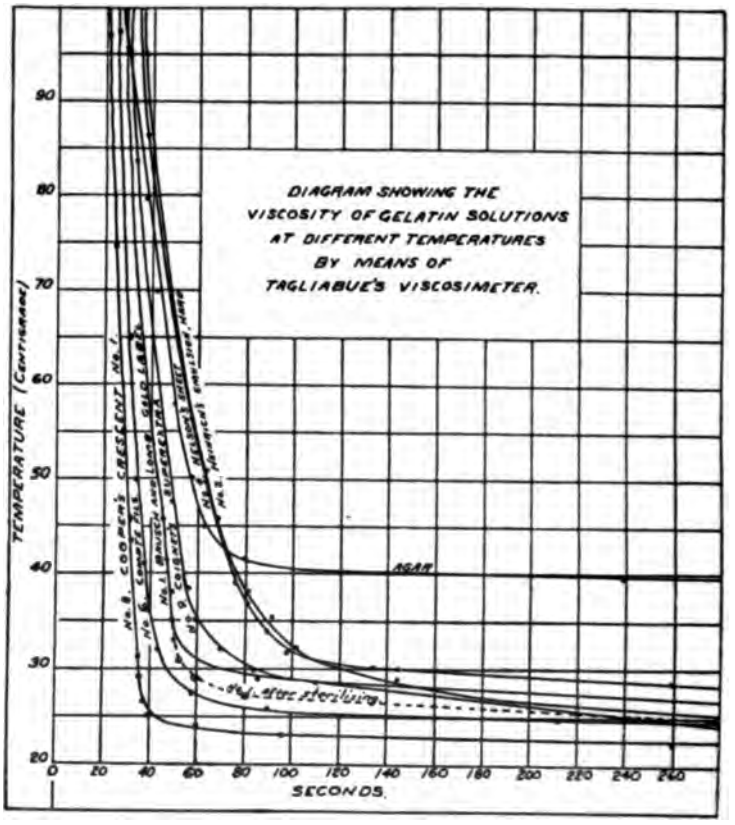

FIG. 2. — DIAGRAM SHOWING THE VISCOSITY OF GELATIN SOLUTIONS AT DIFFERENT TEMPERATURES.

water-jacketed, and there is a boiler to supply steam when it is desired to make the determinations at the boiling-point. A thermometer suspended in the liquid gives the temperature of the liquid as it flows out. With this apparatus the time required for

[1] See trade catalogue of Chas. J. Tagliabue, 51 Fulton St., New York. The instrument is described in most works on oil analysis.

50 c.c. of water at 100° C. to pass through the aperture is 20 seconds; at 20° it is about 24 seconds.

Figure 2 shows the viscosities of 10-per cent. solutions of various gelatins at different temperatures, from the boiling-point down to a temperature at which the gelatins would not flow through the aperture. It will be observed that at 100° C. the time required for 50 c.c. of the gelatin solutions to flow through the aperture varied from 22 to 35 seconds, the average being about 30 seconds. In some cases the solution maintained a comparatively low viscosity until it began to set, or gelatinize, while in other cases the increase of viscosity with falling temperatures was greater, and the point at which setting occurred was approached more gradually. The average viscosity of the gelatins tested at 40° C. was about 55 seconds — which is not far from double the average at 100° C. The viscosities at 100° and 40° C. seem to bear but little relation to the melting-points or the spissitudes of the solutions after setting has occurred. When, however, a gelatin solution has its gelatinizing power impaired by heating, its viscosity at low temperatures is reduced, as shown by the dotted line in Figure 2.

The viscosity of gelatin solutions affects the bacteriologist chiefly in volumetric measurement. A pipette, for example, will discharge a larger amount of a solution at 100° C. than at 40°, because there will be less adhesion of the solution to the glass walls in the case of the warmer liquid. For example, a pipette which discharged 5 grams of gelatin at 98° C. was found to discharge but 4.92 grams at 30° C. This error is usually too small to be taken into account.

Spissitude of Gelatin Solutions.

By the spissitude of a gelatin solution is meant its consistency, or degree of stiffness, or its "jelly-strength," as it is sometimes called. An apparatus used to measure this may be termed a spissimeter. Various forms of apparatus for this purpose are said to be used by manufacturers of glue and gelatin, but these are generally held as trade secrets. In Wagner's *Chemical Technology* there is a description of an apparatus proposed by Lipowitz (see Figure 3). This consisted of a "saucer-like" piece of tinned iron fastened with its convex side downwards at the lower end of a wire. This saucer was allowed to rest upon the surface of the gelatin to be tested, the wire

extending vertically upwards through guides in an iron framework, and terminating at the top in a funnel into which shot could be poured to increase its weight. The iron frame rested upon the sides of the receptacle which contained the gelatin. The weight required to force the saucer downwards into the gelatin, when allowed to stand in 10-per cent. solution for 12 hours at 18° C., was taken as a measure of the spissitude, the greater the consistency of the gelatin the more weight being required.

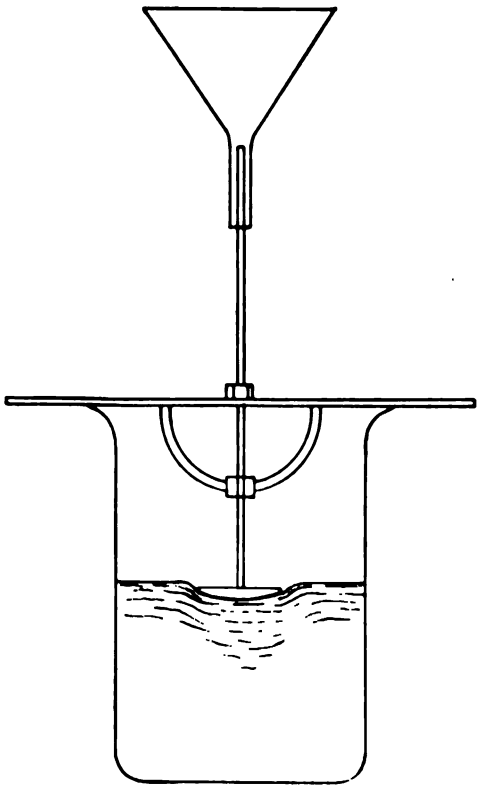

FIG. 3.—SPISSIMETER AFTER LIPOWITZ.

Elaborate methods are in daily use for measuring the viscosity of asphalt,[1] and with suitable modifications these might serve for measuring the spissitude of gelatin solutions. The writer has found, however, that a simpler device, namely, Vicat's[2] apparatus, designed for determining the time of setting of cements, gives excellent results.

VICAT'S APPARATUS USED AS A SPISSIMETER.

This apparatus is shown in Figure 4. It consists of a brass plunger mounted so as to slide vertically in the guides of an iron casting, and provided with an index which moves over a graduated scale screwed to the casting and which serves as a means for measuring the amount of motion. A platform at the top of the plunger offers opportunity for using additional weights, but these are seldom

[1] One of these is described in the Report of the Inspector of Asphalt and Cements, U. S. District of Columbia, for the year ending June 30, 1901.

[2] This is described in almost all works on Cement Testing.

needed, as the plunger without the platform is usually sufficient. A set screw on the side serves to stop movement when desired. The gelatin to be tested is placed in a wide-mouthed bottle, or some other convenient receptacle, and the plunger is lowered until contact is made with the surface of the gelatin, at which point the position of the index on the scale is read. The set screw is then gently loosened, and the plunger allowed to rest its weight upon the gel-

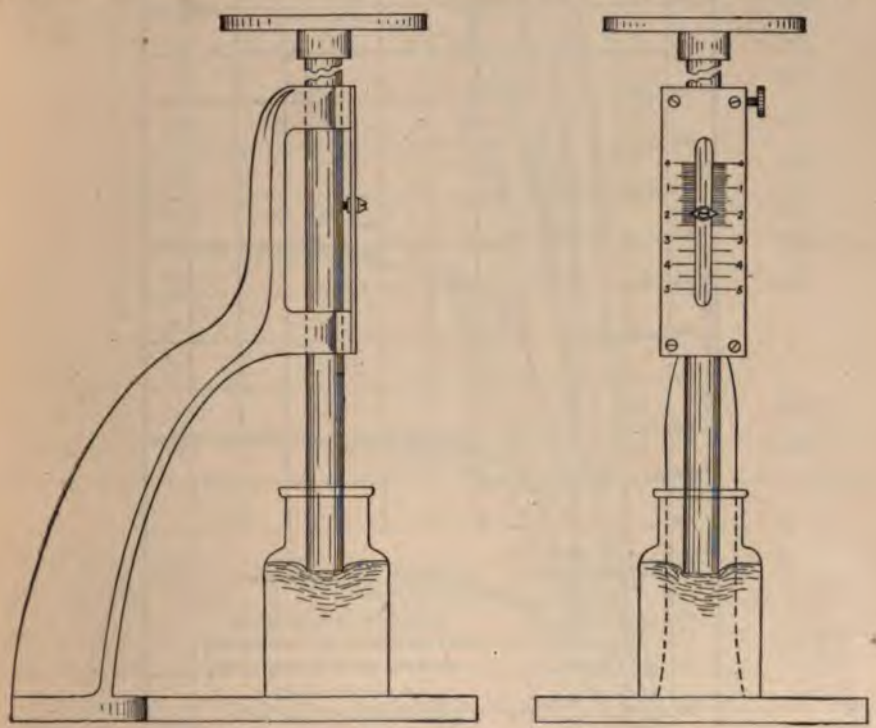

FIG. 4. — VICAT'S APPARATUS USED AS A SPISSIMETER.

atin for about 5 seconds, after which the set screw is tightened and a second reading made. The difference between the two readings gives the penetration of the plunger in millimeters, and this serves as a measure of the spissitude. The scale may be read to 0.1 mm., and except in the case of high readings this figure represents practically the limit of error.

Preliminary experiments were made with aluminum plungers set in wooden rods. Six of these were used, with diameters varying from 3 to 12½ mm., and with loads varying from 25 to 1,000 grams. They

were used with both square and round ends. The results obtained upon a 10-per cent. solution of gelatin which had been kept for 24 hours at a temperature of 20° C., are shown in Figure 5. It was found that the amount of penetration increased gradually with the

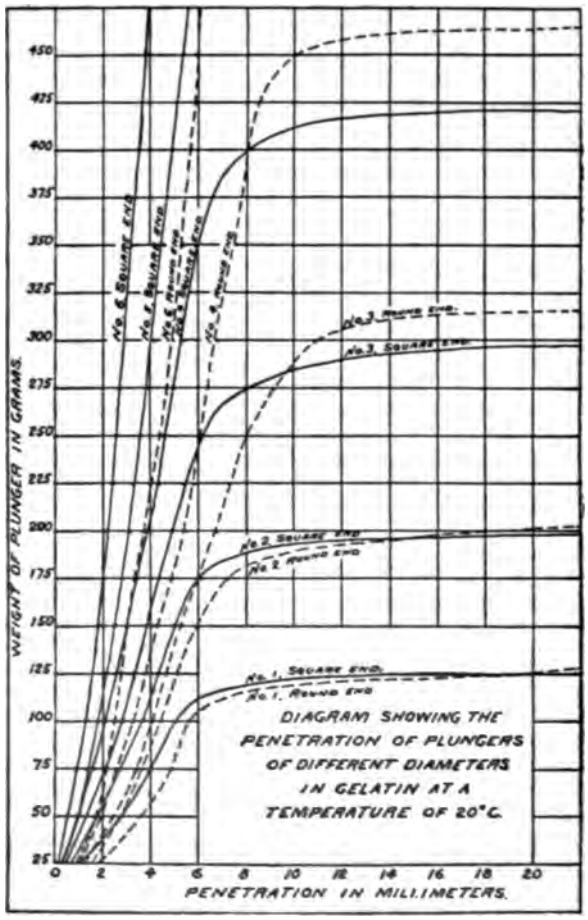

FIG. 5.

load until a certain point had been reached, after which the plunger rapidly passed downward into the gelatin. The weight required to do this varied with the different plungers as follows:

TABLE III.

Number of plunger.	Diameter in millimeters.	Area of cross-section in square millimeters.	End of plunger.	Weight required to produce penetration of 4 mm. (in grams).	Weight required to make plunger sink in gelatin (in grams).
1	3	7.06	Square.	75	125
1	3	7.06	Round.	56	125
2	4.5	15.89	Square.	110	200
2	4.5	15.89	Round.	85	200
3	6	28.26	Square.	157	300
3	6	28.26	Round.	96	325
4	7.5	44.16	Square.	205	425
4	7.5	44.16	Round.	135	475
5	10	78.54	Square.	295	....
5	10	78.54	Round.	....	....
6	12.5	122.41	Square.	475	900
6	12.5	122.41	Round.	220	1,500

It was found that if the weight required to make the plunger sink in the gelatin was taken as a measure of the spissitude, it was preferable to have the lower end rounded; but if the penetration was taken as the measure, the square end was better.

When the square-ended plunger was used, it was found that the weight required to produce a certain penetration of the plunger and the weight required to make the plunger sink in the gelatin increased regularly with the area of the cross section of the plunger. Of the various plungers, that which had a diameter of 10 mm. was selected as giving the best results with the strengths of gelatin solution likely to be used. This, furthermore, was the diameter of the plunger furnished with the Vicat apparatus. Lipowitz's method of observing the weight necessary to cause the plunger to sink was discarded, because the weights required to produce this result were not, it was found, directly proportional to the strengths of the gelatin solutions tested. It was also lacking in sensitiveness and in precision.

The method of observing the penetration of the plunger was found to be much more satisfactory.

The plunger selected for use had a diameter of 10 mm. and weighed 150 grams. It was allowed to rest for five seconds on the surface of the gelatin solution, which was of course parallel to the flat head of the plunger, after which the depth of penetration was read from the scale. By using this apparatus upon gelatin solutions of different percentage strength, it was found that the strength of the solution varied directly with the reciprocal of the depth of penetra-

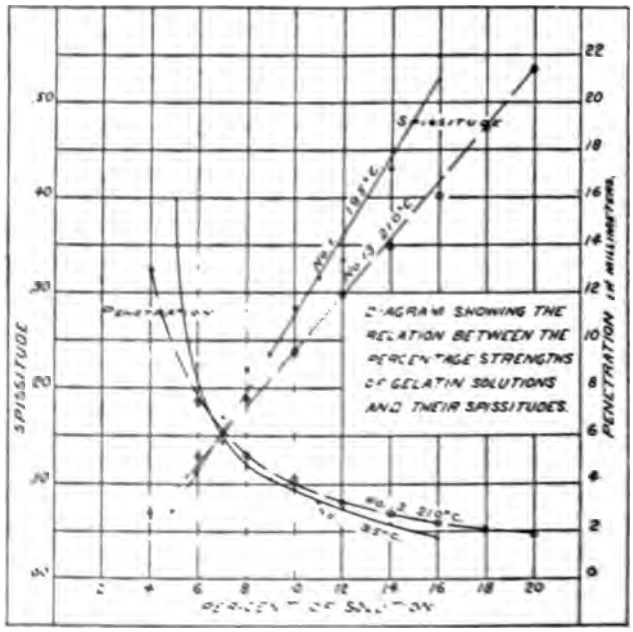

FIG. 6.

tion in millimeters. This may be seen from Figure 6, which shows, by the curves, the depths of penetration after the gelatin solutions had been allowed to stand for twenty-four hours at a temperature of 20° C. Their reciprocals, when plotted, fall approximately in straight lines, and thus furnish a direct measure of spissitude. *The spissitude of a gelatin solution*, therefore, as determined by the method here suggested, *may be defined as the reciprocal of the depth in millimeters to which a plunger having a diameter of 10 mm. and a weight of 150 grams will penetrate when allowed to bear upon the surface of the solution for five seconds. Different gelatins are preferably*

compared in 10-per cent. solutions after they have been allowed to set for twenty-four hours at 20° C. (This strength of solution and temperature are those generally used in bacteriological work.)

In observing the spissitude, it should be noted that if too small a receptacle is used for the gelatin solution, the depth to which the plunger will sink will be somewhat influenced by it. This is shown by the following figures:

TABLE IV.

Diameter of Receptacle in Millimeters.	Depth of Penetration.
95	4.9
60	4.8
45	4.6
15	1 2

With a certain gelatin which showed a penetration of 6 mm. the diameter of the circle of depression was found to be about 30 mm., the plunger being 10 mm. in diameter. With low spissitudes, therefore, it is desirable to use a receptacle somewhat larger than the bottle shown in Figure 4.

Factors which Affect the Spissitude of Gelatin Solutions.

Character of the Gelatin.

Commercial gelatins differ considerably in their jelly-strength, that is, in the percentage of gelatinizing substances present. This is evident from the following table of spissitudes of 10-per cent. solutions determined under the standard conditions mentioned above.

TABLE V.

Number of Sample.	Gelatin.	Spissitude.
1	Bausch & Lomb's Gold Label.	.24
2	Heinrich's Hard Emulsion.	.15
3	Compte Fils' Gold Label.	.11
4	Nelson's Sheet, No. 3.	.23
5	Heinrich's Gold Label.	.34
6	Compte Fils' Gold Label.	.09
7	Cooper's AA Ex. Crescent.	.20
8	Cooper's, No. 1.	.06
9	Coignet's Superextra.	.22
10	Russian Isinglass.	.26
13	Heinrich's Hard Emulsion.	.20
14	Dentelle's Silver Label.	.13

Strength of Solution.

The strength of the solution is naturally of fundamental importance. With a constant temperature, the spissitude varies directly with the percentage strength, as shown by Figure 6. With most commercial gelatins a 1-per cent. solution will gelatinize, and in some cases even a weaker solution will do so if the temperature is low enough; but ordinarily the spissitude at 20° C. of solutions less than 4-per cent. strength is too low to be observed with the spissimeter.

The ratio between spissitude and percentage strength of solution varies, however, with the temperature, as shown by Figure 7, higher temperatures showing less increase in spissitude with increasing percentage strengths than is the case with low temperatures.

Temperature.

Temperature has a most important effect upon the spissitude of gelatin solutions, and with some latitude it may be said that the spissitude varies inversely with the temperature. For example, a 10-per cent. solution of gelatin may have a spissitude of 0.70 at 10° C.; when this is warmed to 20° the spissitude may be .25; at 25° C. it may be .12; and at 30° C. the solution may have become almost, if not quite,

fluid. Different gelatins do not all behave in the same way when heated. Some become soft more rapidly than others. This is illustrated in Figure 8.

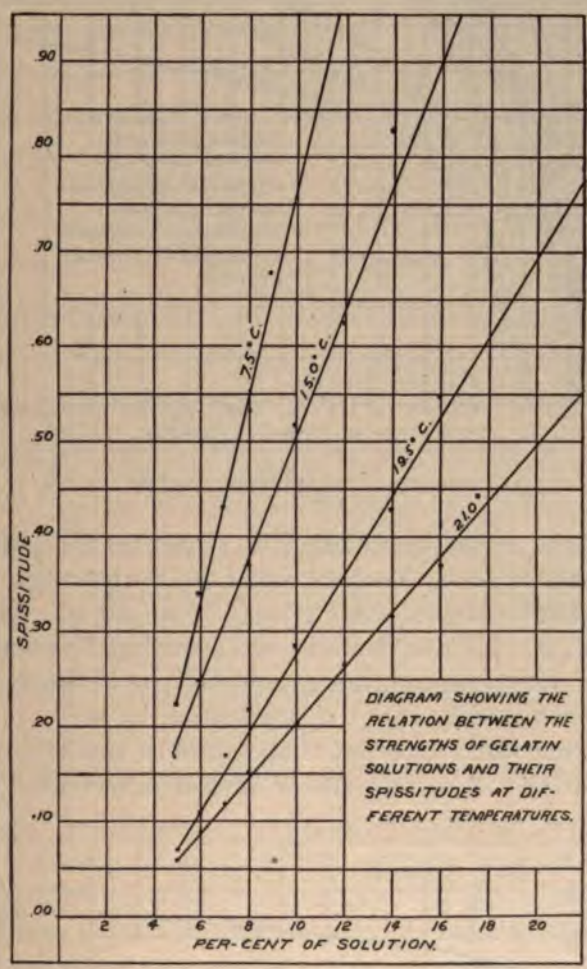

FIG. 7.

Time of Setting.

The setting of gelatin solutions is a gradual process. In the observations of viscosity it was seen that the solution gradually became thicker. The same gelatinizing process goes on after the solution has apparently set. This is seen in Figure 9, which shows the

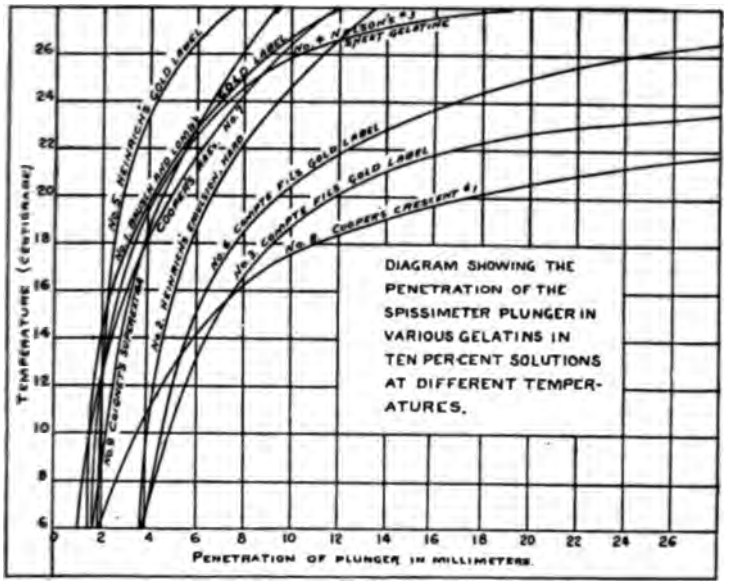

FIG. 8. — EFFECT OF TEMPERATURE UPON SPISSITUDE.

gradual increase in the spissitude of a 10-per cent. gelatin solution, which was maintained at a temperature of 20° for five days. It is said that some gelatins require even a longer time for the spissitude to become constant. Gelatin solutions set more rapidly when cold than when warm. Hence, in comparing the spissitude of different gelatins it is important not only that the observation be made at a definite temperature, but that a constant temperature be maintained while the gelatin is setting. It should not be forgotten, moreover, that when

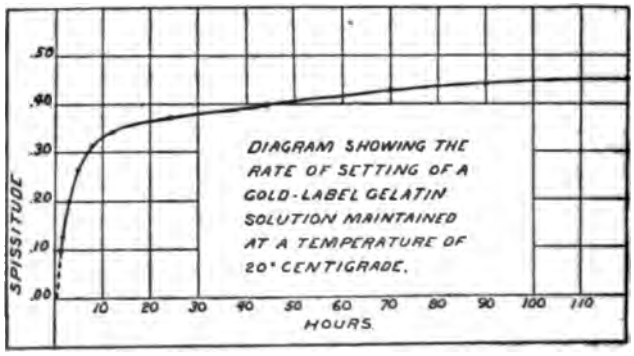

FIG. 9. — TIME OF SETTING.

gelatin solutions are allowed to stand there is an evaporation from the surface, with the consequent formation of a thin skin of gelatin upon the surface of the medium. This evaporation should be guarded against by tightly closing the receptacle or by keeping it in an atmosphere saturated with moisture.

Effect of Heat.

When gelatin solutions are heated, they gradually lose their gelatinizing power. This is of great importance to the bacteriologist, inasmuch as sterilization by heat is an essential part of the preparation of culture media. At the present time two methods of steriliza-

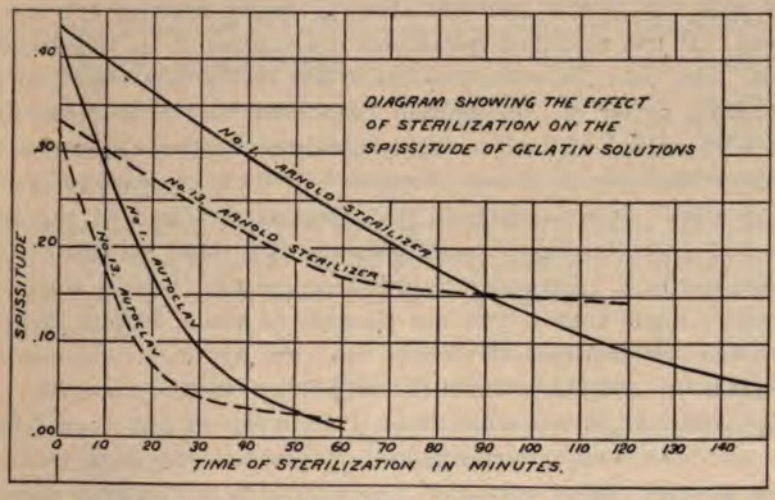

FIG. 10. — EFFECTS OF HEATING FOR VARIOUS LENGTHS OF TIME.

tion are used indiscriminately: namely, heating in streaming steam for fifteen to thirty minutes on two or three successive days, and heating once for ten to twenty minutes in steam under a pressure of ten to fifteen pounds per square inch. Inasmuch as both the temperature and time of exposure affect the spissitude, it is evident that present practice is lacking in exactness. Figure 10 shows the decrease in spissitude of two gelatins in 10-per cent. solution when heated for various lengths of time in an Arnold Steam Sterilizer and in an autoclave. The Arnold sterilizer required about one minute to get up steam after the gelatin was put in. The autoclave required about fifteen minutes to reach a pressure of fifteen pounds. The safety valve was then allowed to blow off, thus letting out the air,

and the time of sterilization was counted from this point. It usually took from two to four minutes for the pressure to return to fifteen pounds. After sterilization the pressure was at once relieved by opening the valve, and the gelatin was removed as soon as possible. The gelatin was tested in two-ounce bottles, like that shown in Figure 4.

It will be noticed that for equal periods of time sterilization in the autoclave has a much greater effect upon the spissitude than sterilization in streaming steam. Ordinarily the time required for sterilization in the autoclave is from ten to twenty minutes (plus the time required to get up steam, which is not usually taken into account), while with the Arnold sterilizer sixty to ninety minutes are usually allowed. If the resulting spissitudes are compared on this basis, it will be seen that the autoclave has a less deleterious effect on the gelatinizing power of the solution than does the Arnold sterilizer. This is in accord with the results obtained by the Committee on Standard Methods of Water Analysis[1] in their comparison of culture gelatins. It was observed that gelatins sterilized in the autoclave had generally higher melting-points than those sterilized in the Arnold sterilizer. Inasmuch as different gelatins behave somewhat differently when heated, it is not possible to find a definite ratio between the two methods of sterilization; but approximately one and one-half hours' sterilization in streaming steam has the same effect on the spissitude as twenty minutes in steam under fifteen pounds' pressure, and one hour's sterilization in steam has the same effect as fifteen minutes under pressure. Discontinuous sterilization modifies somewhat the effect of sterilization in steam. A gelatin steamed for one and one-half hours continuously will have a lower spissitude than the same gelatin allowed to cool on the ice between each half-hour's heating. Manifestly the preliminary heating in the autoclave has an important effect and should be reduced to the lowest possible time.

In establishing a standard procedure for sterilization, it is preferable to decide upon three sterilizations of thirty minutes each in streaming steam, and to allow such time in the autoclave as would produce an equal spissitude of the gelatin solution. This can be easily obtained by experiment for any particular gelatin.

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[1] Loc. cit.

The bulk of the gelatin solution when sterilized has a very important effect on the resulting spissitude. It makes a great difference whether gelatin is sterilized in tubes or in flasks containing, say, 500 c.c. Thus a 10-per cent. solution of Bausch & Lomb's gelatin was sterilized for ten minutes at 115° C. in flasks of 500 c.c. and in tubes of 5 c.c., with the following results:

TABLE VI.

Gelatin.	Spissitude.	Melting-point.
Before sterilization	.22	30.7° C.
500 c.c. in flasks, cooled in the ice chest	.17	28.8° C.
5 c.c. in test tubes, cooled in the ice chest	.06	28.2° C.
500 c.c. in flasks, cooled at room temperature	.13	28.6° C.
5 c.c. in test tubes, cooled at room temperature	.04	27.8° C.

The longer time required for the heat to penetrate the mass of gelatin in the flask is shown in the smaller reduction of its spissitude. The beneficial effect of rapid cooling of the gelatin after sterilization is also shown.

Spissitude of Agar.

Solutions of agar are much firmer than those of gelatin, as shown by the following table; but the solution is far less elastic, and the circle of depression around the plunger is very small. A 1-per cent. solution gives a depression of the plunger under standard conditions of 3.5 mm. (= spissitude .29), while an 0.8-per cent. solution offers so little resistance to the plunger that it readily sinks to the bottom of the glass. Used as a glue, agar has almost no value; but a small amount of agar added to a solution of gelatin increases its spissitude considerably.

TABLE VII.—SPISSITUDE OF AGAR.

Per cent. of Solution.	20° C.	37° C.
0.8	....	....
1.0	.29	....
1.2	.36	.29
1.4	.45	.31
1.6	.50	.36
1.8	.56	.50
2.0	.67	.55

Melting-point.

When a solution of gelatin which has become hard is gently warmed, the mass will first become soft and then fluid. The exact temperature at which the mass becomes fluid is sometimes a difficult matter to determine, inasmuch as a certain time is required for the change to take place. For example, a gelatin solution may remain hard for five minutes at a temperature of 27° C., but if kept for several hours at that temperature it may melt. Then the strength of the solution affects the melting-point to some extent. This is shown by the following figures:

TABLE VIII.

Kind of Gelatin.	Per cent. of Gelatin in Solution.	Melting-point (two minutes' exposure).	Melting-point (five minutes' exposure).
No. 13	1	29.0° C.	29.0° C.
"	2	32.0° C.	32.0° C.
"	4	35.0° C.	33.0° C.
"	6	36.0° C.	35.0° C.
"	8	36.0° C.	35.0° C.
"	10	36.0° C.	36.0° C.
"	12	36.0° C.	36.0° C.
"	14	36.0° C.	36.0° C.
"	16	36.0° C.	36.0° C.
"	18	37.0° C.	37.0° C.
"	20	37.0° C.	37.0° C.

The method of comparison here used was to take 5 c.c. of a 10-per cent. solution in a thin-walled $\frac{5}{8}$-inch test tube and slant the surface as is done for agar cultures; then to immerse this in water and raise the temperature one degree at a time, at intervals of five minutes. The temperature at which the gelatin softened, so that its surface became level, was considered as the melting-point.[1]

The melting-points of the gelatins tested in this manner were as follows:

TABLE IX.

Number of Sample.	Gelatin.	Melting-point.	Congealing-point.
1	Bausch & Lomb's Gold Label.	30.7° C.	23.0° C.
2	Heinrich's Hard Emulsion, No. 9132.	31.5° C.	23.0° C.
3	Compte Fils' Gold Label.	28 5° C.	21.0° C.
4	Nelson's Sheet, No. 3.	28.5° C.	21.0° C.
5	Heinrich's Gold Label.	33.0° C.	22.0° C.
6	Compte Fils' Gold Label.	28.5° C.	21 0° C.
7	Cooper's AA Ex. Crescent.	29.6° C.	22.0° C.
8	Cooper's, No. 1.	26.8° C.	20.0° C.
9	Coignet's Superextra.	28.0° C.	22.0° C.
10	Russian Isinglass.	24.5° C.	18.0° C.
13	Heinrich's Hard Emulsion, No. 1395.	34.0° C.	23.0° C.
14	Dentelle's Silver Label.	28.0° C.	20.0° C.

The melting-point of a gelatin solution bears a more or less direct relation to its spissitude. This is illustrated by Figure 11.

The melting-point of a gelatin solution is lowered by heating. This is a well-known fact, and is sufficiently illustrated by Figure 12.

The temperature at which a gelatin solution will become hard is usually a number of degrees below its melting-point. Time and strength of solution affect this determination also; but the point may be obtained with sufficient accuracy by following the method used for obtaining the melting-point, allowing the bath to cool one degree at

[1] This criterion was suggested by Mr. R. B. Fitz-Randolph, of the Hoagland Laboratory, Brooklyn, N. Y.

five-minute intervals, and noting the temperature at which the gelatin, kept in a slanting position, ceases to flow when the tubes are held erect. The congealing-points of the gelatins experimented with are given in Table IX.

By the addition of various substances to gelatin solutions the spissitude may be raised or lowered, but a discussion of this subject would carry us out of bounds. The substances used in culture media have but little effect on the spissitude. Thus 5 per cent. of pepton reduced the spissitude of a 10-per cent. gelatin solution from 0.21

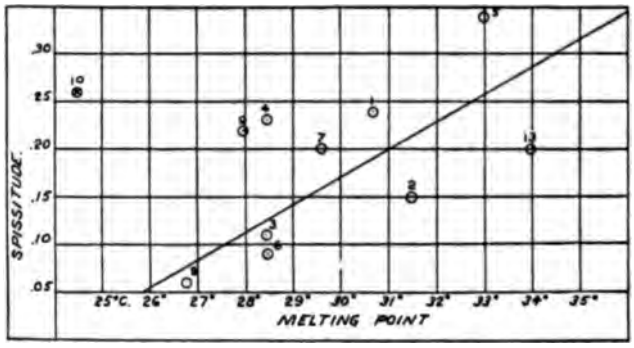

FIG. 11. — DIAGRAM SHOWING THE RELATION BETWEEN MELTING-POINTS AND SPISSITUDES OF GELATIN SOLUTIONS.

to 0.19, while 1 per cent. of salt made an equal reduction. Larger amounts of salt, however, produce greater reductions. Thus:

TABLE X.

Per cent. of Salt in Solution.	Spissitude of a 10-Per cent. Gelatin Solution.
0.0	.26
0.5	.25
1.0	.24
2.0	.23
3.0	.20
5.0	.17
10.0	.10

The reaction of the solution within the limits used in culture media has also no appreciable effect, but extremes in either direction appear to reduce the spissitude. Thus:

TABLE XI.

Reaction of Solution.	Spissitude.
—10.0	.11
—4.0	.26
—2.0	.32
—1.0	.31
0.0	.31
+1.0	.31
+2.0	.33
+4.0	.26
+10.0	.18

Absorption of Water.

Sheet gelatin when kept in a moderately dry atmosphere contains from 3 to 8 per cent. of water. When kept in a moist atmosphere, however, it rapidly absorbs water and becomes soft. The following experiment illustrates this: — Ten grams of thin sheet gelatin (Sample No. 1) were dried to constant weight and then put in a 20° incubator, which had its atmosphere saturated with moisture. After twenty-four hours it had absorbed 18 per cent. of water; after forty-eight hours, 28 per cent.; after ninety-six hours, 32 per cent.; and after two weeks, 45 per cent. It is evident that if the gelatin contains a considerable amount of moisture, this will have an effect upon the strength of the gelatin in the culture medium. Gelatins, therefore, should be kept in a dry place, or else heated before using. Incidentally it may be said that heating the dry gelatin in sheets has no effect on its spissitude.

Reaction.

Most gelatins sold are said to be "free of acid," but when tested by the methods used by bacteriologists this is seldom found to be true. The reactions of the gelatins tested were as follows:

TABLE XII.

Number.	Gelatin.	Reaction.	
		With Phenolphthalien.	With Rosolic Acid.
1	Bausch & Lomb's Gold Label	+ 1.8%	+ 0.6%
2	Heinrich's Hard Emulsion, No. 9132.	+1.2%	+ 0.5%
3	Compte Fils' Gold Label.	+ 2.2%	+ 1.2%
4	Nelson's Sheet, No. 3.	+ 0.4%	— 1.9%
5	Heinrich's Gold Label.	+ 2.2%	+ 1.8%
6	Compte Fils' Gold Label.	+ 2.3%	+ 1.3%
7	Cooper's AA Ex. Crescent.	+ 1.7%	+ 0.5%
8	Cooper's No. 1.	+ 1.7%	+ 0.7%
9	Coignet's Superextra.	+ 2.1%	+ 1.0%
10	Russian Isinglass.	+ 1.5%	+ 0.3%
11	No. 1. Washed.	+ 1.3%	+ 0.4%
13	Heinrich's Hard Emulsion, No. 1395.	+ 1.2%	+ 0.5%
14	Dentelle's Silver Label.	+ 2.0%	+ 1.0%
15	Neutral Gelatin from Zinkeisen & Co.	+ 1.8%	....

It was found that the reaction was not materially altered by boiling.

Effect of the Character of the Gelatin on the Quantitative Bacteriological Examination of Water.

Sedgwick and Prescott[1] in 1895 showed that differences in the character of the gelatin affected the quantitative bacteriological exam-

[1] On the Influence of Variations in the Composition of Nutrient Gelatin upon the Development of Water Bacteria, by Wm. T. Sedgwick and S. C. Prescott. Journal American Public Health Association, October, 1895.

ination of water. They compared culture media made with bone gelatin and hide gelatin with those made with the "ordinary gelatin used in bacteriological work." Their results were as follows:

TABLE XIII. (FROM SEDGWICK AND PRESCOTT.)

Sample.	Number of Bacteria per Cubic Centimeter.		
	Hide Gelatin.	Bone Gelatin.	Ordinary Gelatin.
No. 1	4,170	3,100	3,826
2	2,975	2,960	2,718
3	1,800	1,667	1,488
4	1,800	1,524	1,365
5	1,400	1,246	1,205
6	1,064	1,092	763
7	469	391	219
8	142	148	130
9	120	126	125
10	64	48	42

This introduced a subject which, had it been followed by more extended studies, would have revealed the fact that the gelatin is the most important ingredient of the culture medium, and that different brands of gelatins apparently equal in quality may produce even greater differences in the results than those shown by their experiments.

The comparison of gelatins made by the Committee on Standard Methods of Water Analysis, referred to above, indicated in a general way that the highest results were obtained with those gelatins which had the highest melting-points (see Figure 1). In order to test this more carefully, the writer prepared a batch of nutrient-gelatin in the usual way, divided it into portions, and sterilized these for different lengths of time. This gave a series of media of varying spissitude, but with the chemical composition constant except for such changes as may have occurred during sterilization. These different lots of gelatin were then used to determine the number of bacteria in a sample of Brooklyn tap water, the observations being made in dupli-

cate. The results are shown by Figure 12. It will be seen that the gelatins which had the greatest spissitudes and the highest melting-points gave the highest bacterial counts, and that the counts decreased regularly with the spissitude. The liquefying colonies spread

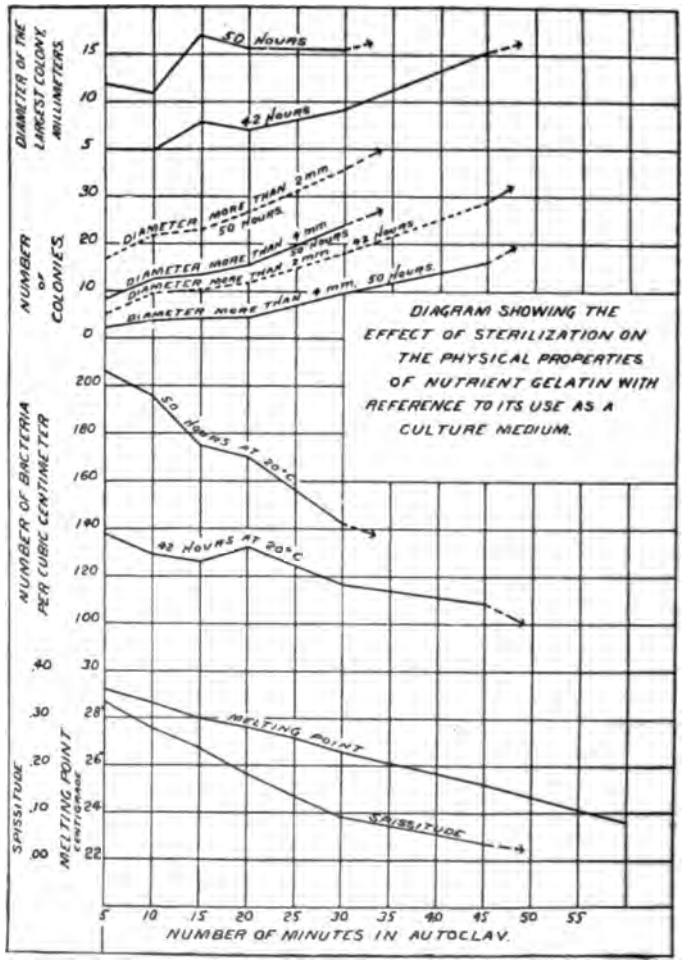

FIG. 12.—EFFECTS OF STERILIZATION.

more rapidly in the thinner gelatins, as may be seen from the increased size of the colonies shown in the upper portion of the diagram. In the gelatins which had very low melting-points, liquefaction of the entire plate occurred before a count could be made. While it was true that the increase of liquefaction in the case of the

thinner gelatins tended to give lower counts, because of obscuration of the smaller colonies, it was doubtful if this was sufficient to account for the great differences observed; and the slight increase in acidity during sterilization did not explain it. Apparently some change in the character of the gelatin occurred on heating which gave rise to products inimical to the growth of certain of the bacteria present. What these changes were has not been investigated.

Nine lots of nutrient-gelatin were then made according to the standard formula, using the various gelatins given in the preceding list. It was intended that all should have the same reaction, namely + 1.5 per cent.; but partly on account of changes during sterilization, the products, when tested, were found to vary somewhat from that figure. The spissitudes varied with the different gelatins, and it was expected that, as before, the counts would vary accordingly, but such did not prove to be the case. Apparently, the differences were due more to different chemical than to different physical qualities. The highest count was obtained with a gelatin of comparatively low spissitude, namely, No. 6. Neither did the size of the liquefying colonies vary with the spissitude. The results of this comparison are given in Table XIV. All of the tests were made in duplicate.

Other lots of media were then prepared with the same gelatins, but with the beef-infusion omitted, in order that a uniform reaction might be more easily obtained. The reaction was made + 1.0 per cent. Duplicate plates of a sample of Ridgewood water were then made, the results of which are given in Table XV. These showed even greater variations than before, the maximum number after seventy-two hours being fifteen times the minimum; and, strangely enough, these two results were obtained by using different lots of the same brand of gelatin.[1]

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[1] It was afterwards learned that Sample No. 3 had been kept in a chemical closet at the bottom of which several bottles of formaldehyde solution were stored. It is possible, therefore, that the gelatin may have absorbed enough of this gas to have a germicidal effect on the bacteria. The absorptive powers of the gelatin molecule are well known, and if the above explanation be the true one, it teaches its own lesson in regard to the storage of gelatin in a laboratory.

TABLE XIV, SHOWING THE NUMBER OF BACTERIA IN BROOKLYN WATER, AND THE SIZE OF THE LIQUEFYING COLONIES WHEN CULTIVATED ON VARIOUS BEEF-PEPTON GELATINS. DATE, FEBRUARY 10, 1902.

Number of gelatin.	Spissitude.	Reaction.	Number of Bacteria per Cubic Centimeter.		Number of Liquefying Colonies Larger than 2 mm. in Diameter.		Number of Liquefying Colonies Larger than 4 mm. in Diameter.		Remarks.
			48 hours.	72 hours.	48 hours.	72 hours.	48 hours.	72 hours.	
1	.21	+ 1.4	56	83	4	28	1	15	
2	.17	+ 1.7	40	105	1	18	0	9	
3	.08	+ 1.4	80	69	13	....	4	28	
4	..	+ 1.3	93	161	9	26	2	17	
5	.33	+ 1.5	84	171	14	31	4	21	
6	.13	+ 1.6	113	210	13	33	3	25	
7	.26	+ 1.7	66	110	10	29	2	13	Fluorescent colonies very brilliant.
8	.11	+ 1.4	62	69	12	28	3	22	"
9	.26	+ 1.7	80	154	10	30	3	15	Fluorescent colonies brilliant.

In this comparison it was noted that gelatins Nos. 2, 5 and 6 contained two colonies of *B. violaceus*; that No. 7 contained one colony, and the others none. There was also a great difference in the occurrence of *Pseudomonas ochracea*, the number of recognizable colonies varying from zero to eleven.

TABLE XV, SHOWING THE NUMBER OF BACTERIA IN A SAMPLE OF RIDGEWOOD RESERVOIR WATER, AND THE SIZE OF THE LIQUEFYING COLONIES WHEN CULTIVATED ON VARIOUS PEPTON-GELATINS. FEBRUARY 18, 1902.

Number of gelatin.	Spissitude.	Reaction.	Number of Bacteria per Cubic Centimeter.		Number of Liquefying Colonies Larger in Diameter than 2 mm.		Number of Liquefying Colonies Larger in Diameter than 4 mm.		Number of colonies of B. violaceus.	Number of colonies of P. ochracea.
			48 hours.	72 hours.	48 hours.	72 hours.	48 hours.	72 hours.		
1		1.0	35	44	6	10	3	5	0	1
2	.10	1 0	105	140	14	20	4	10	2	5
3	.05	1.0	16	17	2	3	0	2	0	0
4	.14	1.0	93	222	15	23	3	7	0	3
5	.10	1.1	87	93	21	24	9	15	2	4
6	.06	1.0	187	258	19	25	7	18	2	11
7	.16	1.1	89	207	10	18	4	9	1	3
8	.08	1 0	75	154	10	16	3	5	0	3
9	.24	1.0	68	156	7	12	1	6	0	0

A sample of ground water was then plated in duplicate with the same set of gelatins. The results are given in Table XVI. In this case no liquefaction occurred in any of the plates, yet the differences in the counts were even greater than before. In some of the gelatins there was but one species prominent, while in others there were two. In some cases the colonies were large and full, while in others they were very small.

Comparison of gelatins Nos. 10 to 15 were then made in the same way with No. 6, which in the previous tests had given the highest figures, and with No. 1. The results are given in Table XVII. In this comparison also No. 6 gave the highest figures. It should be observed that No. 11 gave higher results than No. 1, both of these being made with the same brand of gelatin, but gelatin No. 11 being washed thoroughly and dried before using. It should be noted also that gelatin No. 12 gave a low figure. This was made from a gelatin purified by washing, precipitated in alcohol and afterwards washed and dried.

It is apparent therefore that different gelatins vary greatly in their

nutritive value or in their content of substances prejudicial to the development of bacteria. It is evident also, that bacteria differ in the kind of nourishment required. With certain gelatins some bacteria will thrive while others will not. The nature of the crop depends upon the character of the soil. Just what the conditions are that determine the value of a gelatin for quantitative bacteriological work are still obscure, and are now the subject of investigation. From what has been done, however, it is probable that no one kind of gelatin will support the growth of *all* of the common bacteria found in water to such an extent that their colonies are visible after seventy-two hours at 20° C., and therefore that no gelatin can give the true number of bacteria in water. All results by this method must be considered as having but a relative value, though under the most favorable conditions the counts probably approach the truth with an accuracy sufficient for practical purposes. It is evident also that the results obtained by using different kinds of gelatin are not fairly comparable, —and it seems probable that one cannot even depend upon different lots of gelatin made by the same manufacturer. In order to secure results which shall be fairly comparable it would appear to be necessary to use the gelatin not only of *one manufacturer* but also of *one particular mixture*. It is possible that some manufacturer may be found who will undertake to prepare a special mixture of gelatin of proper quality especially for the bacteriological profession and to make the mixture in such a quantity that it will serve all the bacteriologists engaged in water analysis for several years. Then at the end of that time, if sufficient notice is given, this gelatin may be duplicated with considerable closeness. In the present state of our ignorance of the subject, this appears to be the best that can be done to secure uniform results.

TABLE XVI, SHOWING THE NUMBER OF BACTERIA IN A SAMPLE OF GROUND WATER WHEN CULTIVATED ON VARIOUS PEPTON-GELATINS, FOR NINETY-SIX HOURS at 20° C., FEBRUARY 18, 1902.

Number of Gelatin.	Splasitude.	Reaction.	Number of Bacteria per cubic centimeter.	Remarks.
1	—	1.0	220	One species chiefly. Good growth.
2	.10	1.0	190	One species chiefly. Poor growth.
3	.05	1.0	5	Poor growth.
4	.14	1.0	170	One species chiefly. Good growth.
5	.10	1.1	330	Two species prominent. Good growth.
6	.06	1.0	430	Two species prominent. Good growth.
7	.16	1.1	170	One species prominent. Poor growth.
8	.08	1.0	290	Two species present. Poor growth.
9	.24	1.0	20	Poor growth.

TABLE XVII, SHOWING THE NUMBER OF BACTERIA PER CUBIC CENTIMETER IN VARIOUS SAMPLES OF WATER WHEN CULTIVATED ON VARIOUS PEPTON-GELATIN SOLUTIONS FOR FORTY-EIGHT HOURS AT 20° C.

Number of Gelatin.	Splasitude.	Reaction.	Number of Bacteria per c.c.		
			Sample No. 1.	Sample No. 2.	Sample No. 3.
1	.12	+1.0	310	420	370
6	.09	1.0	800	600	480
10	.18	1.0	675	420	300
11	.14	1.0	675	550	500
12	—	1.0	390	—	—
13	.16	1.0	775	410	360
14	.17	1.0	675	440	380
15	.12	1.0	550	390	380

Effect of the Character of Gelatin on its Use as a Differential Test in the Study of Bacteria.

From the earliest days of bacteriology the "stab culture" in gelatin has been regarded as an important differential test in the study of bacteria, and the character of the growth along the stab has been considered as constant for each particular species. To a certain extent this is true, but in some cases the character of the medium exercises an important influence on the nature of the growth. This was strikingly

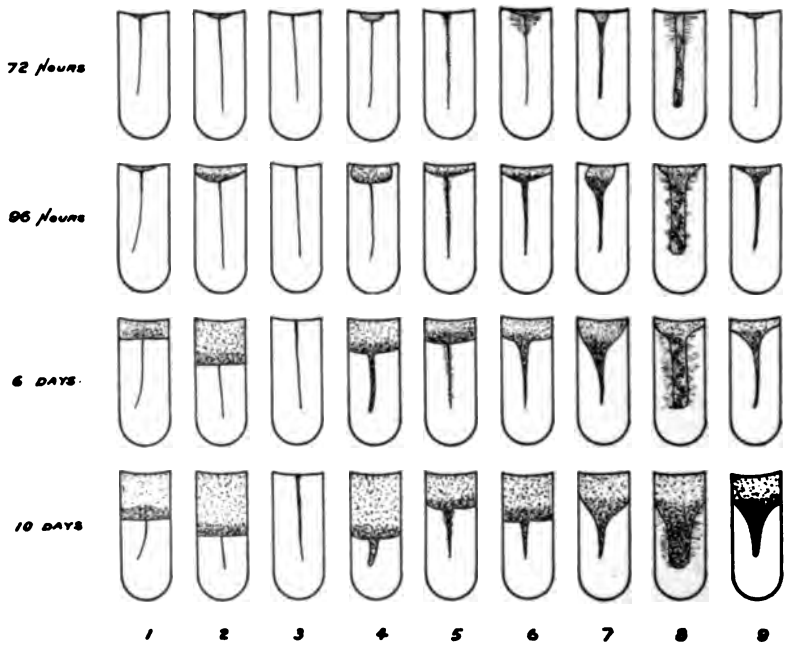

Fig. 13. — Stab-Cultures of Bacillus Liquefaciens in Various Pepton-Gelatins.

exhibited in the following comparison of the growth of certain bacteria in the nine lots of pepton-gelatin already alluded to.

Figure 13 shows the growth of *Bacillus liquefaciens* in these nine gelatins after different periods of time. It will be seen that the growths differed both in their character and in their rate of progress. For example, in No. 3 the growth was very slight; in Nos. 1, 2, 4, 5, and 6 it was stratiform; in Nos. 7 and 9 it was infundibuliform; while in No. 8 it was saccate. Furthermore, in Nos. 5 and 8 the growth was somewhat villous. These characteristics, therefore, cannot be

depended upon as true marks of differentiation in the case of this species.

In the case of *Bacillus fluorescens-liquefaciens* the shape of the stab-growth was about the same in all cases, but the extent of the fluorescence differed materially. Thus in Nos. 1 and 3 it was well marked; in No. 1 it was greenish, while in No. 3 it had a decided orange cast; in Nos. 2, 4 and 8 it was but slightly noticeable, while in Nos. 5, 6 and 7 it was entirely absent, even after ten days. (See Figure 14.)

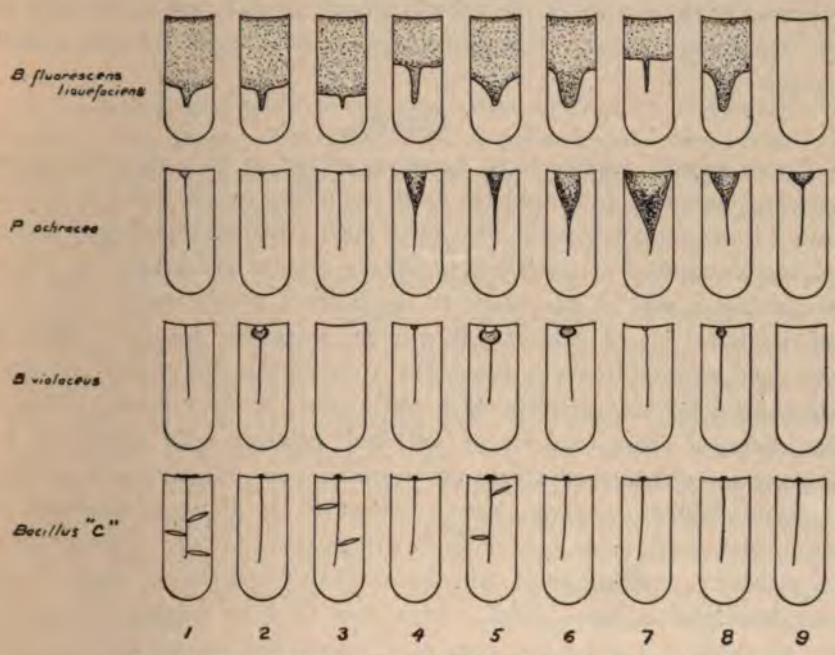

FIG. 14. — STAB-CULTURES IN VARIOUS PEPTON-GELATINS.

Pseudomonas ochracea gave growths which ultimately were much alike in their general appearance, but which differed materially in their rapidity of development. A violet form (probably *Bacillus violaceus*) also showed great differences in its rapidity of growth in the different gelatins. It developed most rapidly in Nos. 2, 5, 6 and 7; in No. 8 the growth was very slight; in No. 1 there was no growth. It will be remembered that on the gelatin plate violet colonies were observed as gelatin Nos. 2, 5, 6 and 7, but not on the others. (See page 154.)

A non-liquefying species recorded as Bacillus "C" gave stab-growths which agreed in their general character, but which differed in that Nos. 1, 3 and 5 showed cracks due to gas-production, while in the others no gas was produced (Figure 14). Inasmuch as no beef-infusion was used in these medias, but only pepton, the fermenting substance must have been present in the gelatin itself.

It is evident therefore that in qualitative as well as in quantitative bacteriological work the character of the gelatin is most important.

The spissitude of the gelatin seemed to have but little effect in determining the nature of the growth along the stab, but in the case of the liquefying bacteria the growth was most rapid in the softer gelatins.

Resumé.

Experimental studies have been presented in this paper to show that the character of the gelatin used in culture media has a most important influence upon qualitative and quantitative bacteriological work, and that for different observers to obtain results which may be fairly comparable it will be necessary to use culture media made from one and the same lot of gelatin. It will be necessary, also, to follow a most rigid system in the preparation, sterilization and use of nutrient gelatin, in order that its physical condition may be the same in all cases. The chemical characteristics of different gelatins with reference to their use in culture media are not discussed, as investigations in that direction are not completed, but the effect of the physical condition of the culture medium on bacterial growth is pointed out. Incidentally the viscosity, melting-point and spissitude of gelatin solutions have been described in some detail, and a new form of spissimeter and a new method of stating the results of spissitude measurements have been suggested.

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ORIGIN AND RELATIONS OF THE AURIFEROUS VEINS OF ALGOMA (WESTERN ONTARIO).

By W. O. CROSBY.

Introduction.

Observations made some years ago in Eastern Algoma, in the vicinity of Sudbury, Whitefish, and elsewhere, and more recently in the new Michipicoten District of Central Algoma, supplemented by a study of the descriptions of the auriferous deposits of Algoma and Nipissing, and notably of the Rainy Lake and Lake of the Woods districts, by Dr. A. P. Coleman,[1] have revealed for this vast area, as also noted by Dr. Coleman, a surprising uniformity in the character of the gold-bearing deposits, as regards alike their geological relations and their structural and mineralogical features. The fact has also been brought out with great distinctness that these deposits, which belong in a general view to the class of veins, are, in the main at least, exogenous rather than endogenous in origin; and the correlation of structure and origin is the main purpose or inspiration of this paper. It is proposed to present: first, the writer's observations in the Michipicoten District; second, a general summary of Dr. Coleman's observations and conclusions, so far as they bear upon the genesis of the veins; and, third, a comparison, in the light of all the pertinent data, of the endogenous and exogenous theories of vein formation, as applied to the auriferous veins of Algoma.

Auriferous Veins of the Michipicoten District.

My observations in this field were limited to the vicinity of Lake Wawa, the south end of which is about six miles in a direct line from Michipicoten harbor; and extended to distances of three to four

[1] Annual reports of the Ontario Bureau of Mines.

miles southeast and south of the lake. Like most of Algoma, this section, although topographically rugged, is heavily forested; the depressions are largely of a swampy character, and a thick bed of moss covers both hills and valleys, so that prospecting is difficult and opportunities for geological investigation are largely confined to the lake shores and the mines. The Michipicoten Mining District embraces the Huronian area which, as recently mapped by Coleman, extends from the northeastern corner of Lake Superior northeastward to the Canadian Pacific Railroad. As admirably exposed in the vicinity of the Helen Iron Mine and elsewhere, the Huronian series consists of a great and complex development of slates, quartzites, schists, etc., besides the great beds of pyrite and siderite in which the iron ores have their origin. Intersecting these undoubted sedimentary deposits — the true Huronian — is an extensive complex of igneous rocks, of both acid and basic types, but consisting chiefly of granites (often gneissoid), felsites (often altered to sericite schists), diorite and gabbro, which are also extensively altered to massive or schistose greenstone. It is perhaps improbable that the igneous rocks all belong to the same or nearly the same period; but there seems to be no reason to doubt that the diorites, of which the gabbros are, perhaps, a more basic phase, are, as usual, closely related to the granites, representing a differentiation and earlier crystallization of the same magma. The diorites grade into the granites and have been, along their common boundaries, extensively penetrated and enclosed by the latter. In the past the diorites have usually been referred to the Huronian, and the granites to the Laurentian; which, as noted later by Lawson, Adams, Coleman and others, makes the Laurentian clearly newer than the entire Huronian series. The gneissoid or foliated structure of the granites, as of the felsites and other types, may, in part, be regarded as secondary and referred to dynamic metamorphism; but in large part also, it is clearly original and essentially flow structure developed under pressure. The latter explanation would account especially for the very prevalent gneissoid borders of the granite areas.

In the vicinity of Lake Wawa, the granite is prevailingly a rather fine-grained, biotitic variety, passing at some points into a granite porphyry, the prominent rounded blebs of quartz suggesting a typical quartz porphyry. This variety is well developed near the southeastern shore of the lake. In the diorite also, the dark constituent

is chiefly biotite, and, in part, as in Mackey's Point on the southeastern shore of Lake Wawa, quartz is a prominent constituent, giving a more or less typical quartz diorite.

The veins of the Wawa area clearly belong to two distinct types, which may be briefly described as (1) branching gash veins in the massive diorite, and more rarely in the massive interiors of the granite areas; and (2) non-branching, but usually sheeted or composite, veins occurring in the foliated zones of the granite, and very commonly on the border of the diorite. It can hardly be doubted that, in this instance at least, the basic rocks, referred to here collectively as diorite, have been a much more important factor than the granite in

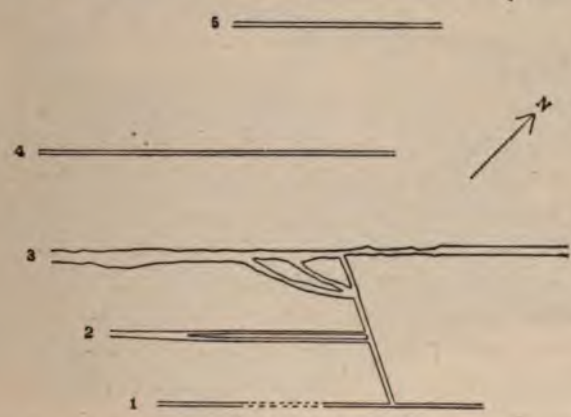

FIG. 1.—GROUP OF VEINS ON THE SOUTH SIDE OF MACKEY'S POINT, LAKE WAWA.
Scale: 1 inch = 60 feet.

the formation of veins; although the foliation of the latter rock has determined the locus of one important structural type.

Gash Veins.—Probably no clearer or more instructive examples of the veins of this type are exposed in this area than those on Mackey's Point on the southeast side of Lake Wawa, where the first discovery of gold in the Michipicoten District was made. Mackey's Point, which is embraced in mining lot Y 103, is a sharp ridge of massive, black, biotitic, quartz diorite, jutting into the lake. On the southern slope of the headland is the branching series of veins shown in Figure 1. This is seen to consist chiefly of five parallel veins, from 1 to 4 feet in thickness and having a general northeast-southwest trend, and a northwest dip, which varies from 35° to 70°. But veins 1 and 3 are connected by the cross vein which

does not intersect either, and from which vein No. 2 is best regarded as a double branch, since no trace of it is to be seen on the northeast side of the cross vein. The abrupt variations in width of vein No. 3 and its branching connection with the cross vein are significant. Figure 2 shows in detail the branching termination of vein No. 2. In both form and grouping these are typical gash veins, understanding by that term, veins formed in joint cracks without important displacement or faulting of the walls. Owing to the extremely massive character of the diorite and the absence of displacement, enclosed fragments of the wall rock are few, except where, as shown in the figures, blocks of the country rock, often of considerable size, are isolated by the branching of the veins. That the fissures

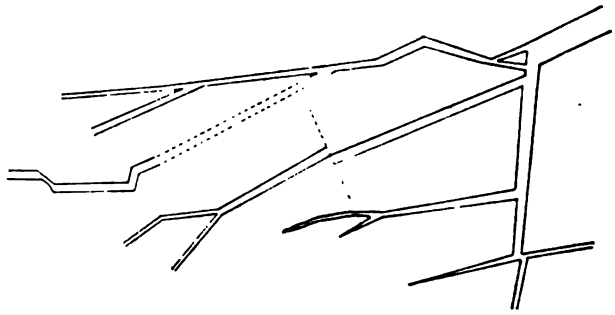

FIG. 2.—DETAILED BRANCHING OF ONE OF THE VEINS SHOWN IN FIGURE 1.
Scale: 1 inch = 10 feet.

are not due to faulting movements is shown by the general absence of slickenside and selvage phenomena, the vein material being, as a rule, firmly welded to the walls. In general, near all the larger veins, and there only, as a rule, the diorite is more or less distinctly chloritized, this alteration yielding at some points a typical greenstone, and being particularly noticeable in the enclosed masses of diorite. The walls of the veins are, in most cases, very regular and sharply defined, and the contacts are not suggestive of a metasomatic replacement of the diorite. The veins consist chiefly of massive quartz in which the sulphides — pyrite and pyrrhotite — occur sparingly and very irregularly, considerable bodies of quartz being, apparently, entirely free from the sulphides. Alteration of the vein contents since the close of the Ice Age has been slight; and the unoxidized sulphides are usually found within a few inches or a

foot or two of the surface. Tourmaline, in slender, black needles imbedded in the solid quartz, is a common, though rather inconspicuous, feature of the veins; and green chlorite, evidently derived from the dark constituents of the diorite, occurs in the significant forms shown in Figure 3. A normal banded or comb structure and vugs or pockets are wholly wanting; and the only thing to be noted in the way of a definite internal structure is the dark line, sometimes to be observed, as in Figure 3, dividing the vein midway

FIG. 3. — QUARTZ VEIN ONE INCH WIDE IN THE DIORITE OF MACKEY'S POINT.[1]
The median line represents the primitive crack along which the formation of the vein began; and masses of chlorite are seen extending outward from this line to the walls.

and parallel with its walls. Although, as stated, there is no true selvage, the diorite, where most completely altered to greenstone, may be divided, as usual, by slickenside surfaces, which may, or may not, be parallel with the walls of the vein.

The best explanation of these veins seems to be that they are not only true gash veins formed in the joint cracks of the diorite, but that they are also a product of segregation from the diorite; or, in other words, they have been formed by lateral secretion. We have

[1] The photographs for this and all of the following illustrations were kindly furnished by Mr. John L. Gardner.

an abundant source of the free silica or quartz in the greenstone alteration of the diorite; and the sulphides, both pyrite and pyrrhotite, are throughout a notable feature of the diorite. The question next arises as to whether they are in origin endogenous or exogenous. That is, were they formed in preëxisting, open fissures; or like a concretion or a root in the soil, did they make room for themselves as they grew? Quite certainly, many of the smaller veins of this class are completely isolated in the diorite, occurring as thin, lenticular sheets of limited extent in depth and strike, and lateral secretion is, obviously, the only permissible explanation for these.

An exogenous origin or growth from the middle outwards is indicated by the massive structure, the absence of a true comb structure and vugs, and the angular inclusions of the country rock unsupported by the wall. The general idea is that the veins began to form in incipient cracks, or possibly along merely potential fractures, the formation of which may be supposed to imply relief of pressure which would favor the deposition of dissolved minerals. The veins, thus inaugurated, are widened and extended as long as the supply of material from the enclosing country rock is kept up. In the case of the examples represented by Figure 3, the dark median line represents the primitive crack from which the vein has grown either way, forcing the walls apart; and the enclosed masses of chlorite do not represent inclusions of the diorite, but rather a free crystallization of chlorite derived from the wall-rock, localized in obedience to the principle of segregation, and showing a tendency to increase in breadth outwards, as if the supply of chlorite became more abundant through a gradual acceleration of the greenstone alteration of the diorite. It is noticeable that this pure, soft, green, crystalline chlorite is strictly confined to the veins, and separated by a sharp line of demarcation from the partially chloritized diorite of the wall. The sulphides, although distributed very irregularly, as regards the major dimensions of the veins, are found mainly near the walls, suggesting very plainly that they should be, like the chlorite, regarded as a recrystallized residuary portion of the diorite. Again, the sulphides are clearly most abundant in that part of the diorite immediately bordering the vein, and farthest advanced in chloritization; and there is thus some ground for the view that they are in part derived from the ferruginous silicates, as has often been suggested for other and more important occurrences.

Accompanying the quartz veins, and yet essentially distinct from them, are veinlets of a crystalline, ferruginous carbonate, which proves on examination to be ankerite. Unlike the quartz veins and veinlets, these often have decidedly irregular outlines; and the contacts with the diorite, although sharp, as shown in Figures 4 and 5, suggest replacement, rather than a mechanical displacement or separation of

FIG. 4 — BRANCHING VEINLETS OF ANKERITE IN THE DIORITE OF MACKEY'S POINT. Three-fourths natural size.

the walls. The discontinuance of the ankerite vein shown in Figure 5, without any signs of a break or slip in the diorite, affords a specially clear indication of replacement. The ankerite veins or vein-like substitutions are also a feature of the massive granite, having in some cases a thickness of from one to several feet, and showing a perfect gradation from thin impregnations to complete replacements.

That these carbonate replacements have been derived from the immediately surrounding wall-rock there can be no question. At the surface they are usually oxidized to yellow ochre. The carbonate veinlets find a ready explanation in the percolation of meteoric waters carrying carbon dioxide and free oxygen and carbonating the lime, magnesia and ferrous iron of the silicates, and sulphating

FIG. 5.—VEIN OF QUARTZ AND BLIND VEINLET OF ANKERITE IN DIORITE OF MACKEY'S POINT. Two-thirds natural size.

the disseminated pyrite, the ferrous sulphate reacting with the carbonates of the alkaline earths to increase the amount of ferrous carbonate or ankerite. The silica set free by the carbonation of the protoxide bases of the silicates probably contributes to the formation of the quartz veins.

In the massive interiors of the granite areas the gash veins occur less frequently than in the diorite, but vary in width up to five and even ten feet. Also they are less given to branching and partake more of the character of true fissure veins. Mineralogically and structurally, however, there is no essential difference; and in the massive character of the quartz and absence of true banding, combs or vugs, as well as in the isolated inclusions of the wall-rock,

bear evidence of their exogenous origin. The gash veins are rly not to be sharply distinguished in character or origin from sheeted veins ; and, doubtless, many intermediate forms occur.

Sheeted Veins.—As previously stated, the veins of this type are ined to the foliated zones of the granite. These zones, whether are to be interpreted as original flow structure or the product

IG. 6.—LENTICULAR VEINLETS OF QUARTZ IN FOLIATED GRANITE FROM THE HORNBLENDE MINE. Two-thirds natural size.

ubsequent shearing, are in either case essentially the product of amic metamorphism and appear to be chiefly confined to the nity of the granite-diorite contacts, or at least to the contacts wo different products of the general granitic magma. The veins e closely with the foliation of the granite in both trend and dip are rarely vertical; and, as is customary with veins in foliated schistose rocks, they exhibit in general outline and in detail a lency toward a lenticular form, as is very strikingly shown on a ll scale in Figures 6 and 7. These are relatively short, thick and

distinctly overlapping lenses; and their wedge-like relations to the foliated structure of the granite is very noticeable. In other instances, and in most of the larger veins, the enclosed plates and slabs of the wall-rock are a very important feature. These are always parallel with each other and with the wall of the vein, which may consist in large part of these inclusions or partings, actual veins, and sometimes the same vein, showing every gradation from a solid vein

FIG. 7.—LENTICULAR VEINLETS OF QUARTZ IN SCHISTOSE AND CHLORITIC GRANITE FROM THE MINTO MINE. Two-thirds natural size.

of quartz to a band of schist with interlaminated veinlets, as represented on a small scale in Figure 7. These inclusions are very commonly isolated by the vein matter and afford one of the most cogent arguments for the exogenous origin of these veins. The veins vary in width up to ten feet or more, although comparatively few are above five feet; and the proportion of vein matter to inclusions varies inversely as the schistosity of the wall-rock.

As regards the character of the vein matter, the sheeted veins

have much in common with the gash veins. Quartz is the chief gangue mineral and the sulphides include pyrrhotite and pyrite chiefly, with some chalcopyrite and occasionally small amounts of sphalerite and galenite. The most noticeable difference in the composition of the two classes of veins is found in the fact that the crystalline carbonate or ankerite which is wanting in the gash veins, but forms associated substitution veinlets, is in many cases a direct constituent of the sheeted veins, in which it sometimes occurs in great abundance. Its relations to the quartz, as shown in Figure 8, prove

FIG. 8. — ASSOCIATION OF QUARTZ AND ANKERITE IN THE MINTO MINE.
All the dark material is coarsely crystalline ankerite superficially brown by oxidation.
Three-fourths natural size.

their contemporaneous deposition. It is very coarsely crystalline or sparry, while the quartz, as before, is entirely massive; and, as in the true gash veins, true banding, comb structure and vugs are conspicuous by their absence. Tourmaline, in clusters of slender, black needles shooting through the quartz, occurs more or less sparingly in both classes of veins and has given the name Hornblende Mine to one of the mines in the vicinity of Lake Wawa. In both types of veins, also, the gold is chiefly free, in the main fairly coarse, and very irregularly distributed. To determine the percentage of free gold, twelve samples ranging in value from a trace of gold to 2.60

ounces per ton, and averaging .90 ounce per ton, were treated by amalgamation; and the gold saved was found to range from 23 to 100 per cent. of the assay value, the average saving being 77 per cent., and distinctly higher for the high than the low values.

Summary of the Structural Features of the Auriferous Veins of Algoma. Compiled from Reports by A. P. Coleman.

It is proposed to cite here only such portions of Dr. Coleman's reports as appear to be specially pertinent in their bearing upon the structure and origin of the veins. In the interests of brevity the citations often are not literal or continuous, and hence quotation marks are omitted.

General Observations and Conclusions. — All the important gold districts of Algoma, or Western Ontario, are in the Huronian series, if we assume that Lawson's Keewatin is in reality of that age.[1] Gold has been found in a stretch of country reaching from near the Manitoba boundary for a distance of two hundred and sixty miles; and over a breadth of one hundred and twenty or thirty miles. Gold in paying quantities will not, however, be found everywhere within this area; for probably two-thirds of this territory is Laurentian, which has never proved to be auriferous except near the margin of the Huronian.

In general, the granite forming the country rock for gold-bearing fissure veins is apt to be modified by shearing and weathering into a greenish rock, often called protogine, in which the mica or hornblende of the original granite is changed into sericite or chlorite. Generally the change has gone still farther at the immediate edge of the vein, the feldspar being changed to sericite and other products, the rock taking on the look of a schist, probably as the result of faulting when the fissure was formed and of the action of circulating water during the filling of the vein.[2]

It was formerly held that gold and other metals were to be looked for in Ontario only in the Huronian, the Laurentian being considered barren. It has been found, however, that some of the most promis-

[1] Fourth Report Bureau of Mines, Ontario, 1894, p. 39.

[2] Fifth Report Bureau of Mines, Ontario, 1895, pp. 86–87.

ing gold deposits occur either in granite or in gneiss; and further, that both in the granitoid rocks and the green Huronian schists the best veins or other ore deposits occur at or near the contact of the two kinds of rock.

The source of the gold deposits in our rocks is not easy to determine. The fact that they almost all occur near the contact of granitoid eruptive rocks with the Huronian suggests that one or other of these rocks furnished the original supply of gold, probably by lateral secretion. In the case of small lenses we cannot assume fissures reaching to great depths, so the adjoining rocks must have contained the gold afterwards concentrated in the fissures opened by the pushing up of granite masses into the Huronian schists. Gold has frequently been found in the country rock immediately beside veins, but probably this has been deposited from the solutions circulating in the veins themselves.

The auriferous fahlbands of the Huronian may have been supplied with the metal in the beginning, or they may represent shear zones where the rocks have been so shattered as to allow solutions to percolate and deposit sulphides with gold. The eruptive masses carrying gold almost certainly brought the metal up with them from the depths where they originated.

The great quartz lenses of the Sultana Mine are found at the northwestern edge of an oval boss mapped by Lawson as Laurentian. The enclosing rock, mapped as Keewatin, is green, fine-grained and not distinctly schistose. The boss of Laurentian consists in its central part of coarse-grained, gray granite, with phenocrysts of orthoclase half an inch wide. Going westward towards the edge of the boss, the granite slowly becomes schistose, showing distinct parallelism of structure, and the porphyritic feldspars are rolled out into imperfect *augen* or lens-shaped portions. Near the Crown Reef the coarse gray gneiss passes rapidly into the fine-grained, dark gray gneiss of a very schistose kind, and then into very fine-grained brown-black mica schist with crumpled strips or lenses of quartz. The large quartz lenses in which the mine is worked lie in this schistose edge of the boss, and contain many thin sheets or thicker bands of the dark schist.

As one approaches the edge of the boss, the signs of crushing and shearing grow intense. The quartz shows "mortar" structure, being crushed into fine particles enclosing larger fragments. The

feldspars are broken and portions shifted asunder, calcite sometimes serving as cement. At the very edge, the quartz is rolled out into streaks of crushed particles, the feldspar largely changed into a mixture of sericite and brown mica, and calcite and sulphides appear in considerable quantities. At the extreme edge little is to be seen in thin sections but brown biotite in minute scales.

It may be imagined that the granite, while still somewhat plastic, *i. e.*, not yet cooled to the point of consolidation, pushed up through the Huronian rocks, more or less shattering them and dragging out its own margin into the present schistose form. Before the process was complete the sheared edge of the mass was solid enough to allow the formation of great cavities between the layers of gneiss and mica schist. Here the fluids of the now solid but still hot granite could circulate, depositing the auriferous quartz.[1]

True Fissure Veins. — True fissure veins are most commonly found in the areas of eruptive granite, and form important gold deposits in many cases, having a continuity and uniformity not usually found in the other types. The best known examples are those of Shoal Lake on Seine River, where an area of coarse granite six miles in length by one or two in breadth contains scores and perhaps hundreds of well-defined veins running in various directions. The granite is of the green "protogine" variety, a very siliceous plagioclase, or soda granite, in which there is much sericite; and it pushes up through Huronian rocks that had been greatly disturbed in ages long previous to the eruption.

Many of the fissure veins in the Huronian schists are narrow and very crooked and irregular, and they are often associated with larger bedded veins. In that case the narrow cross (fissure) veins are generally much richer than the others.[2]

Bedded or Lenticular Veins. — The bedded, lenticular or segregated veins belong especially to schistose rocks, just as the true fissure veins are confined chiefly to massive rocks. They are generally lenticular in shape, and when a lens runs out another often replaces it a little to one side. Frequently several layers of schist are more or less parted, bands of quartz of varying thickness filling the spaces between, when the ore body may have quite ill-defined limits;

[1] Sixth Report Bureau of Mines, Ontario, 1896, pp. 119, 120, 121, 122, 123.

[2] Ibid., pp. 115-116.

but in many cases the lenses have tolerably definite walls, though seldom so distinct as in the case of true fissure veins, and the two kinds are not to be looked on as totally different in character, since both must have been at one time open fissures through which water circulated. But they are not usually so continuous horizontally and vertically as true fissure veins and the quartz is more often quartzitic in look than in the other class.

The term "segregated," frequently used for these ore deposits, seems less correct than "bedded," since it implies a mode of formation by lateral secretion or segregation which is by no means proved. In fact, it is probable, as stated above, that these veins are filled with mineral matter very much as fissure veins are.[1]

A most interesting example of lenticular veins is found in the Sultana Mine, the country rock being a gray schist probably formed by the shearing of a mass of porphyritic gneiss as it pushed up through Huronian rocks.

Veins of this description in Huronian rocks are by all means the commonest form of gold deposit in Ontario. They vary greatly in size, shape, and importance. Often one finds a great number of small crumpled stringers of quartz with schist between, the whole uniting at some point perhaps to larger quartz masses, but without any well-marked walls. In other cases there are well defined bands of quartz with fairly good walls, and traceable even for miles.[2]

Fahlbands. — Fahlbands, or bands of schist impregnated with pyrite and other sulphides, are not infrequent in the Huronian rocks of Ontario. Frequently some quartz is embedded between the pyritous schists, forming a connecting link with certain bedded veins.[3]

Rainy Lake Region. — The more important ore deposits in the neighborhood of Rainy Lake are of two kinds, bedded or segregation veins and true fissure veins, the latter being much less common than the former.[4]

At the little American Mine, Keewatin schist encloses numerous small bedded veins of quartz, with iron and copper pyrites and a little white calcite.[5]

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[1] Fourth Report Bureau of Mines, Ontario, 1894, p. 50.

[2] Sixth Report Bureau of Mines, Ontario, 1896, pp. 116–117.

[3] *Ibid.*, p. 118.

[4] Fourth Report Bureau of Mines, Ontario, 1894, p. 50.

[5] *Ibid.*, p. 53.

The Lyle Mine on Dryweed Island is operating on bedded quartz veins in green Keewatin schist. The quartz contains pyrite, a carbonate, probably dolomite, and some black tourmaline.[1]

Between Bad Vermilion and Shoal Lakes the granite, which is coarse grained and a typical granite, flesh colored and with black mica in unaltered parts, becomes modified into a greenish, chloritic granite, the so-called protogine, near the vein; and at its very edge is changed into a greenish, schistose rock, consisting of quartz veins and chlorite or sericite, but almost entirely free from feldspar. This band of modified granite probably results from a shearing motion which had ground down the softer minerals when the fissure, no doubt accompanied by faulting, was formed. The circulation of hot water in the fissure probably completed the change of the crushed feldspar into sericite masses.[2]

Lake of the Woods Region. — Almost all the gold locations in the Lake of the Woods region appear to lie along the disturbed margin of the Laurentian and Keewatin; gold-bearing veins, both bedded and true fissures, occurring within the Laurentian gneisses, as well as the Keewatin schists, as though they partook more or less of the nature of contact deposits. If the gneiss is really a species of plutonic rock which has heaved up, fissured, and folded the already solidified Keewatin, the occurrence of veins along and near the contact seems very natural, for these convulsions must have opened up many channels for the flow of water, highly heated by the molten or half-molten rock beneath, the very conditions favorable to the deposition of ores. In this respect the Lake of the Woods gold region seems to differ greatly from that of Rainy Lake, where scarcely any important gold-bearing veins have been found near the edge of the Laurentian, and none whatever within the Laurentian.[3]

At the Keewatin Mine, Big Stone Bay, small bedded and gash veins occur in green schist. The quartz contains a little black, slaty rock, pyrite, and slender, radiating prisms of tourmaline.[4]

The deposit of the Scramble Mine is an excellent example of a fahlband, though some quartz is embedded between the laminæ of

[1] Fifth Report Bureau of Mines, Ontario, 1895, p. 63.
[2] Fifth Report Bureau of Mines, Ontario, 1895, p. 66.
[3] Fourth Report Bureau of Mines, Ontario, 1894, pp. 68–69.
[4] Sixth Report Bureau of Mines, Ontario, 1896, p. 97.

schist. The rock is mica schist or mica chlorite schist, and the vein rock differs from the adjoining country in being heavily impregnated with pyrites.[1]

Upper Seine Region. — On Reserve Island a bedded vein contains white and greenish quartz, with some galena and iron pyrites. The vein has well-slickensided walls, at least in some parts, and the country rock is protogine granite, but in places chlorite schist shows itself associated with the quartz. Another vein of white quartz contains some green schist and has one good wall of granite.[2]

At Sawbill Lake the vein is about four feet wide. The quartz contains pyrite, chalcopyrite, galena and some free gold. The country rock is an imperfectly foliated gneiss. A microscopic examination shows that much of the rock is a tolerably fresh, biotite granite gneiss, but that the parts near the vein are greatly altered.[3]

Wahnapitae Region. — In general there are considerable differences between the geology of this gold region and that around Lake of the Woods and Rainy Lake. In the more westerly gold district quartzites are rare, and graywacke only moderately prevalent, while green schists are the commonest rocks. As a general rule, too, in the western region gold is found chiefly near the contact of Huronian with the Laurentian gneiss and granite. Here, however, gold deposits are found eight or ten miles away from the nearest Laurentian contact.[4]

At the Mammoth Vein, the white quartz, sometimes fifty or more feet in width, can be followed more than a quarter of a mile. With the quartz is much of a coarsely crystalline carbonate, weathering brown, and a few sulphides. In large vugs, immense crystals of quartz with much-corroded surfaces are found.[5]

Discussion.

The foregoing citations from Dr. Coleman's reports suffice to show that the vein phenomena of the Michipicoten district are not local or unique, but on the contrary, are fairly typical of the whole region, or at least of the entire length and breadth of Algoma. The uni-

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[1] *Ibid.*, p. 108.

[2] Sixth Report Bureau of Mines, Ontario, 1896, pp. 74–75.

[3] *Ibid.*, p. 76.

[4] Report Bureau of Mines, Ontario, VII, Part II, 1898, p. 136.

[5] *Ibid.*, p. 138.

formity of the general geologic conditions throughout this vast area is matched by the uniformity of the auriferous veins, and, perhaps in less degree, of other classes of ore deposits. Everywhere are recognized two main types of veins, Dr. Coleman's fissure veins clearly corresponding to what I have described as gash or joint veins.[1] And the gash veins and sheeted or bedded veins are alike and always characterized by massive quartz, free from true comb structure and vugs, accompanied in many cases by sparry, ferruginous carbonates and ferruginous sulphides, with occasional slight developments of other sulphides and of slender crystallizations of tourmaline. Also, the gold occurring in the veins of either type is chiefly free, often fairly coarse, and likely not to be evenly distributed, limited bodies of rich quartz often alternating with much larger bodies of very low grade or nearly barren quartz. In general, the enclosing formations, at least in the immediate proximity of the veins, exhibit more or less metamorphism — dynamic (shearing) or chemical (chloritization), or both. The dynamic metamorphism has to a large extent determined the locus of vein formation (sheeted or bedded veins) and the chemical metamorphism has supplied in ample measure the free silica, carbonates and sulphides, and probably the gold and other minerals, required for the formation of the veins.

The origin of both types of veins by segregation, or lateral secretion from the enclosing formations, is indicated alike by the structure and the composition ; and ascending solutions have apparently played no important part here. In fact, they are inconceivable for the isolated lenses and fahlbands, as noted by Coleman, and are demanded by no known facts, lateral secretion fulfilling perfectly, so far as we know, all the requirements of a complete explanation. Elsewhere, however, as we have seen, Coleman questions the sufficiency of the lateral secretion theory, even for the sheeted veins, and suggests that they are probably filled with mineral matter very much as fissure veins are. In comparing the two main types of these auriferous veins, and noting that they are not to be regarded as totally different in character, Coleman states that both must have been at one time open fissures through which water circulated; and it is not clear that he regards the formation of the veins in the absence of preëxisting open fissures as always possible.

[1] I prefer to restrict the true fissure veins to those occupying fault fissures and which are thus persistent in depth and characterized by slickensided walls and other selvage phenomena.

That the veins of both types are, in the main at least, of exogenous origin, that is, have been formed in the absence of preëxisting open fissures, by growth from the middle line outward, the growing vein mechanically displacing and not chemically replacing the wall-rock to make room for itself, is, to my mind, clearly indicated by the leading facts. Endogenous vein formation by incrustation on the walls of an actual or preëxisting open fissure, and the formation of vein-like replacements, are familiar conceptions; but true exogenous vein formation by segregation without replacement along a plane of weakness or in a merely potential fissure, the vein crowding back the walls as it grows and making room for itself in the solid rocks much as a root does in the soil, is a more novel idea. These are unquestionably the conditions under which many crystals and concretions are formed in the rocks; and they may safely be postulated for such isolated lenticular veins as those represented in Figure 6, since correlation with pure concretions, mechanically distorting and displacing the enclosing rock as they grow, is clearly preferable to the supposition that cavities of these forms were developed by plication and subsequently filled, and since replacement, metasomatic or otherwise, is ruled out by the perfect conformity of the veins and walls.

Among the normally distinguishing features of endogenous veins may be mentioned banding or comb structure and vugs, crystalline and botryoidal or mammillary mineral developments being directed inward (centripetal growth), and absence of isolated inclusions of the wall-rock save where there is evidence of a reopening of the fissure. Exogenous veins, on the other hand, should, normally, be distinguished by a massive structure, outward facing (centrifugal growth) of local and definite mineral developments, whether distinctly crystalline or not, and, very generally, by a median line or surface marking the primitive break and the inception of growth, and above all, by isolated inclusions of the wall-rock. The comb structure represented by the transversely fibrous or columnar structure of veins or veinlets of asbestus, chrysotile, satin spar, etc., is also believed to be extremely characteristic of, and essentially peculiar to, exogenous veins, while slickensided walls are entirely consistent with both modes of formation.

Judged by these criteria, the auriferous veins of Algoma, alike of the gash and sheeted types, are clearly exogenous, or at least the

truly endogenous examples must be of very exceptional occurrence; for they are massive, devoid of true comb-structure and vugs, and both isolated lenses and isolated inclusions of the wall-rock are highly characteristic.

They occur in a region of ancient rocks, perhaps the oldest on the continent, and a region also of extremely prolonged geological stability and subterranean inactivity, during which the erosion has unquestionably been enormous — to be measured by thousands of feet and probably by miles. We must logically, or according to the well-established precedents, refer the formation of the auriferous veins to the period of disturbance and metamorphism accompanying and following the folding of the Huronian strata and the development of the igneous complex, and to a time, therefore, anterior to the stupendous erosion which over wide areas has laid bare the ancient zone of flow and even the still deeper zone of fusion. Endogenous veins are clearly limited to the zone of fracture, where only open fissures can be formed and maintained; while exogenous veins may, in fact must, also characterize the deeper zone of flow, being co-extensive with every phase of the process of segregation directly dependent upon the molar or molecular movement of water in unfused rocks. In other words, the endogenous and true fissure veins of this region have, in general, disappeared with the ancient zone of fracture in which they originated; but the exogenous veins and replacements, comparable with pure concretions (concretions consisting wholly of the segregating mineral), which are, respectively, non-metasomatic and metasomatic in their relations to the enclosing formations, still persist, although individually of limited extent; and it is a necessary corollary of this view that their mineral contents, including their metallic values, have been derived from the immediate environment by some phase of the process known in general terms as lateral secretion.

That ore deposits of these types are now forming in this region (except possibly at a great depth), or have been formed in a geologically recent past, is improbable; but we may confidently assume that they belong to a remote past, and refer them to the deep region (not necessarily the zone of flow) where only is possible the greenstone alteration or chloritization of the granite, diorite, etc., which has supplied the quartz, carbonates, sulphides and other materials for the making of the veins.

SUCCESS IN LONG-DISTANCE POWER TRANSMISSION.

By F. A. C. PERRINE, D.Sc.

Read May 8, 1902.

Two elements make success in the long-distance electrical transmission of Power — Continuity and Regulation.

Perhaps these are the most important elements in any electrical undertaking and are the most obvious, but in attaining our ideal in long-distance work, there lurk pitfalls about these two elements unknown in other fields of the art.

From the outset in the original studies, and down the line to the last switch and insulation, lie unknown problems and problems known, but unsolved. It is the field of the thoughtful, independent engineer; the ground is stony and fit traveling only to the most resourceful.

Hydraulic development is one of the oldest arts, but the amount of human ignorance concerning hydraulic problems and conditions is appalling. Records may have been kept of the rivers whose waters are navigable, or whose rapids and falls are along the railroad lines, or in the manufacturing villages; but an investigation of the records available concerning important powers, even a few miles out of the regular lines of travel, would surprise you by their lack of accuracy and detail. Rainfall has been kept for generations for the benefit of agriculturalists, but the watershed of no one power stream of my acquaintance has ever been completely covered in its essential details by rainfall records.

The water available at any one point where the rainfall can be approximated will be estimated by different engineers from 15 per cent. to 70 per cent. of the total fall, and, apparently, each will be justified by engineering precedents. Such possible variations call for the exercise of caution, judgment, and experience in reaching conclusions.

Nor is there less uncertainty in regard to hydraulic construction. The present year has seen the failure of dams built by engineers of the highest reputation and at water pressures for which they were supposed safe. The flow in canals, ditches, flues, and pipes, are still subjects of

dispute, and errors in design are continually leading to serious results for the investor.

The one lesson to be drawn from all this being that, if continuity only means success, the studies in water-power location must be made with unusual care, and ample, though never ridiculous, margins allowed in the estimates.

Perhaps the day may come when the civil engineers will establish their empirical equation in hydraulics on a sure basis, but until that day is reached, and it is not near, the hydraulic engineer can never cease to be a student and most careful observer. In almost all cases the formulæ of engineering have a sound experimental foundation, but the error has actually been made of attempting to apply results obtained from the gaugings of the Mississippi to small rapid rivers, and even in some cases to lined canals and timber flumes, and an equal error committed of attempting to apply the results obtained from the flow of water in eight and ten inch pipes to great conduits and even open flumes. No smile should arise over the absurdity of these errors, for every state in the Union has instances of them, and no year in the past twenty but has seen them committed to the waste of thousands and hundreds of thousands of dollars. The records for the past five years at one of our most respected testing flumes are at fault on account of an altered pressure pipe and an uncorrected formula. Success comes to the cultured engineer who keeps close to his borrowed data and who solves for himself the unforeseen problems.

I mean by "Culture" what Matthew Arnold means when he says that culture is "A pursuit of our total perfection by means of getting to know, on all the matters which most concern us, the best which has been thought and said in the world."

Such an engineer with such an ideal will be a safe guide and his studies will establish on a firm basis our transmission undertaking.

But we are not concerned tonight with the errors of the civil engineer, or with his unsolved problems, so much as with what is new and with what is gradually getting to be known in electrical problems. While these are no more important nor more interesting than the hydraulic problems, they are attracting more attention, and perhaps it is in apology for our electrical ignorance that I call attention to hydraulic difficulties and ignorance. It is true that in no other art can so accurate calculations be made as in electrical engineering, but there are many facts and constants for our equations still unknown.

Even in the electrical art there is still an unknown, and I suppose that no one of us will live to see the discovery of even all the knowable our art contains. I am reminded now of the beautiful equation for the dynamo machine presented twenty years ago by Clausius, which contained a round dozen of unknown constants, and though we have since discovered the values of some of his constants, others have been found to have been variables, and we are still studying the problem and searching for the others.

Regulation in direct current work is a simple problem. Its laws are all known; at every lamp it is quite easy to predict the variation of voltage. The same laws control whether the lines be long or short. In his transmission plants Thury has met no new difficulties but has effected regulation at ten or twenty miles, just as he would have done had the delivery been made only in the next room to his dynamos. Resistance is always resistance and his dynamo characteristics remain unaltered by its increase. He deals only with current, voltage, and resistance and encounters problems simple even to Faraday, Henry, or Ohm.

It has been said very truly that the introduction of the alternating current raised the electrician above the rank of the artisan. With these currents he is no longer dealing with a few simple independent quantities connected by a primary rule, but must now consider many new elements, some constants and some variables. At every step capacities and self-inductions enter into the solution in complex and involved relations. Regulation can no longer be simply determined for each part of the system independently, and the regulation of the whole obtained by a consideration of the parts separately. Self-inductions and capacities affect each other, and the generators and lines, as well as the transformers and motors must be chosen or designed with this interdependent relation in view. A simple case illustrates this beautifully.

When the operation of the transmission supplying current to the city of Stockton, California, from the power plant at Mokelumne Hill, forty-six miles away, was first begun, a curious state of affairs was observed. In operation of the lines alone, the current required on the 2,200-volt side of the step-up transformers was sixty amperes; with the step-down transformers connected, the current fell to about fifty amperes, and when a 100 K. W. motor was put into operation the current was only fifty-five amperes. The transmission was designed

to be at 25,000 volts, but at the delivery end of the line the voltage was found to be 27,200 volts, and finally the motors consumed full current when running at no load and not much more when operating with full load applied.

I think that all will agree that here are problems enough for one small instance of the difficulties in the regulation of a long-distance transmission plant.

The lines in this case had been calculated for an eight-per cent. loss of energy for transmission of 1,000 K. W., and capacity played the most important part in these pranks of voltage and current. With the lines alone, the capacity was so great as to absorb an apparent energy of over 130 kilo-volt-amperes. This is reduced when the transformers are connected and some real energy begins to flow and the self-induction of the step-down transformers neutralizes some of the capacity of the line.

When the motors are connected, the real energy is increased and the self-inductances of the various parts of the system become more important.

The apparent rise of voltage along the line illustrates the interdependence of the whole system even more clearly, for it is only in a very small part due to the line itself, or rather, while due to the line, it occurs in the step-up transformers and not to any extent along the line.

It is not uncommon to attribute such an effect to resonance, which really only rarely becomes important; in reality, the regulation of the transformer produces this effect. With any transformer fed with a constant voltage at the primary, the secondary voltage falls with non-inductive load and falls still further if an inductive load is applied, but if the load is a capacity load, the secondary voltage rises instead of falls. In this case, therefore, the step-up transformers were delivering a ten-per cent. higher voltage to the line than their transformation ratio accounted for, which necessarily disturbed the regulation seriously. This trouble became even more serious when a heavy induction-motor was later operated by the same plant. The load on the motor accounted for a fall of potential amounting to four per cent., but the inductance produced a drop of ten per cent. at least; and, as the rise of voltage on the line at no load was as much as ten per cent., it may at once be seen that the voltage varied when the motor was connected from ten per cent. above normal to ten per cent. below, and thus a

variation exceeding twenty per cent. was produced in place of a variation of four per cent. for which the load allowed.

The effect upon the synchronous motor was also due to this ever troublesome capacity. The generators were giving nearly a true sine wave of E. M. F., while the motors were designed for a peaked wave, the line capacity so affected the generator wave that the difference between the motor and generator became great, and for part of each wave the motor was absorbing power, and for its remainder delivering power, so that always a great current was flowing.

In this particular case these troubles were corrected by the introduction of a heavy self-induction across the ends of the line which neutralized the line capacity; and this self-induction was used until an inductive load was connected in the shape of induction motors, which rendered the use of an extra self-induction unnecessary.

Whenever this arrangement can be thoroughly carried out and the capacities and self-inductions connected to any line be evenly balanced, the alternating problem can be reduced to the simplicity of the direct current problem and long algebraic equation abandoned in determination of the expectations.

This possibility is beginning to be appreciated and regulation attained in long-distance transmissions which could not otherwise be hoped for.

There is little service which calls for absolutely continuous power. Most plants, which are said to be operating "day and night," shut down at meal times and are rarely operated more than twenty hours of the twenty-four, and even where the operation is continuous through the day, there is a cessation of operation on Sundays and holidays. For this reason, it is difficult to satisfactorily balance the capacity of the line against the inductance of any load. The line capacity current is constant and is continuously in evidence so long as the voltage is applied to the line; indeed, it varies only with the voltage and periodicity. Its importance increases as the load diminishes, for when the load is heavy it is not only completely overcome by inductance, but also is rendered unimportant by reason of the presence of a large current in phase with the electro-motive-force. During the time when all loads are diminished, the disturbance of regulation by reason of the presence of a line capacity-current is most apparent, and consequently the counteraction of that capacity effect, by a heavily inductive load which is off during these same periods, is a remedy which

only accentuates the disease. This was illustrated in the case described above where a severe induction load depressed the voltage and its removal allowed the full rise due to line capacity.

In the case of the Standard Electric Company's transmission and that of the Bay Counties Power Company, where transmission of approximately 150 miles at 50,000 volts and 60 cycles are undertaken, the charging current is approximately 40 amperes; or, in other words, the line requires the full capacity of a 2,000 K. W. machine for charging it as a condenser. The complete neutralization of this great capacity-effect would require the continuous working of something in excess of 5,000 K. W. of induction motors with average normal power factors.

Up to the present time no load on the Bay Counties lines has ever been applied which is capable of neutralizing this capacity effect. The Power House is practically unable to have much knowledge of the loads actually applied on the lines except by observing the wattmeters or the wheel nozzles, since the current from no load up to a load of several thousand kilowatts remains practically constant. As there are many branching lines supplied from this system, it is impossible to operate other than with constant E. M. F. at the dynamos, and the regulation of the long lines is affected by the capacity, which influences everything from the step-up transformers to the last motor.

In order to overcome the troubles due to this source, the Bay Counties Company have arranged to place upon their lines impedance coils capable of practically neutralizing the entire capacity of their long lines; and, as soon as these are installed, one of their greatest difficulties in obtaining satisfactory regulation will be removed. With the capacity of the line neutralized, it then becomes necessary to keep the load as nearly non-inductive as possible by continuous care in the balance of synchronous against induction motors in the operation of loads.

It is a great mistake for an engineer to become an advocate of one motor to the exclusion of the other type. Both synchronous and induction motors have their spheres of usefulness, and practically every long-distance transmission demands for its satisfactory regulation the use of both types. Where the powers are small and the loads easily started, the simplicity of the induction motor and ease of installation renders it especially suitable, but as their numbers increase, the effect of the lagging currents they absorb becomes important in disturbing regulation, so that it soon becomes necessary to neutralize this lagging

current either by the introduction of condensers or of synchronous motors.

With a synchronous motor it is possible to counteract the effect of large and variable inductive loads, and, when they are installed in the sub-station at the delivery end of the line, a ready and satisfactory means of controlling the voltage, whether it is disturbed by inductive or non-inductive loads, is provided. Practice with these machines indicates, however, that they are still very useful if installed at points out of control of the sub-station attendants, provided only that their power of controlling voltage be not used maliciously, since they are generally most useful when the exciting current is adjusted to a minimum; a condition for which instructions are easily issued and of which the reasonableness appeals to the most ignorant attendant.

Much has been written and said of the resonant condition of a line, but up to the present time practice in the installation of plants and connection of motors, transformers, and other devices has not led to important interference from this source. What is called the resonant line, or distortionless line, can be obtained in two ways, either by the connection of capacities and inductances in series, or by their connection in parallel. In the first method of connection there is a very serious rise of potential at the respective terminals of the capacities and inductances, but with the parallel connection no such rise is found. The series connection of capacities and inductances is rarely used and, principally, on account of the difficulties likely to be encountered on account of these phenomena. The exact balance of inductances against the capacity of a line fifty or one hundred miles long, capable of supplying some thousands of kilowatts, would result in a voltage rise of not less than ten times the value of the normal; and, when one considers that this normal may be anywhere between twenty-five and fifty thousand volts, it is easily seen that such resonance may be formidable. Such an effect is sometimes actually encountered in the operation of switches on lines where considerable cable lengths are used in feeding highly inductive apparatus. In a recent case an arc within a partially broken cable feeding rotary transformers, by raising the periodicity and producing apparently a resonant condition, caused the effect of most violent short circuits, blowing fuses with great violence and destroying both fuse holders and switches, currents appearing entirely beyond the capacity of the generating apparatus to maintain. When the proper inductances are connected in parallel, however, their action

is beneficial to regulation and easy to handle, as has already been explained.

What has so far been said covers fairly well the question of purely electrical problems of regulation, and to call your attention to the essentials of the problem, it only needs the summary that regulation in a long distance plant is attained by —

First. A wide possible voltage variation in the generators, with generators and transformers both designed, not for good non-inductive load regulation, but for good inductive load regulation.

Second. Lines designed for the smallest possible capacity current without reference to any attempt at balancing the line capacity against the load lag.

Third. The use of reactance coils for balancing the constant capacity of the line.

Fourth. The use of synchronous motors as a variable capacity for balancing the variable inductance of the line and the inductive motor load.

Of the elements of design which involve most nearly the question of continuity, supreme importance attaches to the insulators, the switches, and the lightning arresters.

To be sure, the entire problem of continuity is also the whole problem of design. Everything must be built to withstand the strains, and the methods of accomplishing this are neither easy nor obvious; many of the well established methods of conveying and controlling water must be abandoned in favor of those which are more enduring. Open ditches and flumes are giving way to enclosed and lined trenches and tunnels.

For station structures, the extreme of strength and fire-proof character must be resorted to and the whole transmission line must be built for the greatest permanence. Spans are shortened even in some cases to only one third of that used in telegraph and telephone construction. Heavier poles are employed, most carefully set, and braced against even the slightest increase of strain. Rights of way are secured and cleared so that these transmission lines stand up against the storms and fires that lay waste the countryside.

But returning now to the purely electrical part of the problem with which we are most directly concerned for the present, and directing our attention to the insulators, which present the first and most difficult problem, we find at the outset a royal battle waged between

the insulating properties of glass and porcelain. In this country glass has for many years been the king of the insulators; abroad for an equal period of time, porcelain has remained preëminent.

For potentials up to about 25,000 volts, where an insulator of seven inches diameter is sufficient, there seems not much reason for the employment of anything except glass, unless the lines reach a size above half an inch in diameter, when its strength is deficient. For these lower potentials and lighter lines the good properties of glass are easily summarized. In the first place, it is cheaper by far; while not so strong as porcelain, it is, as has already been said, sufficiently strong for the purpose; its inspection is easier and surer, since it requires only a visual examination and a few taps of a hammer to ascertain its soundness in place of the tedious high potential test necessary in the examination of porcelain. But having said this much, all has been said that is possible in favor of glass.

It is not true that glass is a better insulator than sound porcelain, nor is its surface so good in damp weather against surface leakage. The mechanical strength does not equal one half that of porcelain, as has been proved by a long series of mechanical tests performed by dropping a steel ball from a height upon insulators of the two materials; temperature also affects it much more than porcelain and it is often found to crack simply from the effect of extreme changes of temperature.

The insulators for high voltage lines must be very large, for the reason that with a striking distance through the air of from four to six inches, great gaps must be provided in the path of the current. But above all a great creeping distance is essential.

Insulators that are a perfect protection in the hardest rains fail utterly in clear weather when covered by smoke and soot, which allow small amounts of currents to escape and char away the pins or cross-arms. The compound insulator is very attractive, for the reason that it is easier and cheaper to make and handle two or three small parts rather than one large one, and in some cases the additional advantage has been sought of securing the good properties of both glass and porcelain by making parts of an insulator of each; but there is both a theoretical and practical fallacy in this type of design. In the first place, no dielectric is so strong as one entirely homogeneous. As the stress is passed from glass to porcelain, or *vice versa*, at the two surfaces the stress piles up as it were, and it is better if one believes in glass to rely upon it; or, on the other hand, to show faith in the porcelain used by employing it entirely.

From the pure standpoint of practice the insulator which must be cemented together is troublesome. The shrinking of the mastic leaves voids and produces strains; if cement be used, its slowness in hardening delays the work and requires large areas for setting out to harden any considerable number of insulators. The one other mastic in use is molten sulphur, which, while better as a mastic than cement, is still more liable to crack the insulators while they are being joined, and finally when exposed to light and air, frequently decomposes on the surface, producing sulphuric acid; and, finally, when current creeps over its surface following the acid, perhaps, catches fire and often results in the rupture and fall of the insulator. The insulator which will be entirely satisfactory for this use has not yet been found, but the diligent search made for it by some of our best engineers is resulting in its definition and will probably soon result in its production, not as an inspiration for a patent, but as a careful engineering conception.

Switching and switching devices are most important and most difficult. Step by step the switch has improved in the electrical art from the simple commutator used by Faraday and Henry, which generally consisted of copper wire dipping into mercury cups; until, as you know, up to the present time a great amount of ingenuity devoted to the study has resulted in the production of elaborate and beautiful electrical and mechanical mechanisms. Switching for high powers, whether at low potential and great currents or at high potential and small currents, seems to be an altogether different art from switching where the spark that may follow can do but little destruction, and its heat is readily dissipated. Almost all low-power switches are designed with the idea that a spark may occur at the break, but as the energy of the spark is small, the mass of the switch will carry away the heat, or the portion of the switch destroyed will be inconsiderable and may be easily replaced; but as soon as it becomes impossible to contemplate the destruction of a portion of the switch in the rupture of the current, switching becomes impossible by such simple devices, the whole art of switching is changed, and designs along entirely new lines must be produced. The great pneumatically controlled switches in the large power stations of New York and Boston exemplify this principle. Hardly anything in switching for small currents is similar. They are not simple switches, giants in size, but their method of operation is based upon a new principle and they involve in their construction much ingenuity and engineering study. As even the great switches with

which you are familiar operate only on lines where the potential is comparatively low, the principles of high voltage switching need to be particularly called to your mind. In any high voltage transmission system as, indeed, in any transmission system, the lines and loads contain not only resistance but also capacity and self-induction. The current flowing depends upon the E. M. F., the frequency, and the constants of the circuit in an involved relation. A change in any one of these constants involves changes in the resultant current. A satisfactory switch must leave the circuit undisturbed as far as possible, and must introduce no new difficulties by reason of changed values of the constants. Furthermore, if a switch could be built which would simply instantaneously stop the current, the effect would be an immediate and great rise of potential due to the sudden fall of current through the capacities and self-inductions of the system. The open air switch which, in its essential particulars, is simply that of the ordinary knife, or snap, switch as used for low potential, draws an arc at almost full current value, which arc, being rapidly oscillating in character, effects an increase of the periodicity on the line and thereby brings about great potential rise. We see, therefore, that a switch to be satisfactory on a high potential circuit must neither rupture the circuit too suddenly nor draw an oscillating arc. With ordinary switches in mind, the rupturing of a circuit with these requirements in view seems to be almost an impossibility; and, were there no means of introducing into the path of the switch blade high resistances which gradually reduce the current value, and finally allow the stoppage of the flow of energy after it has become small in amount, we would have to provide in insulation of our long-distance high-potential lines, materials which would withstand voltages from two to ten times the normal voltage. Of course no wire wound or carbon rheostat can be introduced into these switches, and the only resistances that are available are liquid and gaseous resistances. It is almost too soon to say that any particular type of switch has resulted from the experiments of the past two years which will be considered for all years to come the final type; but the successful work that has been done is along the line, as I have said, in the introduction of liquid and gaseous resistances. These resistances are the only ones that are high enough in value to be enclosed in the small space of a switch and which do not introduce additional complexities into the station system. The gaseous resistance is obtained in the oil switch by the carbonization of the oil as

the switches open; provided there be a sufficient amount of oil above the switch contact, so that as the circuit is opened the production of gas does not blow the oil out of the switch, a very satisfactory type of switch is produced, and one which our present experiments seem to indicate, will gradually cause the rupture of a circuit without the production of excessive rise of potential.

The vaporization of metallic oxides has also been successfully used for this purpose, but when these oxides are vaporized in the switch, it is difficult to retain them within the switch and they scatter their dust through the whole station. The liquid switch is one of the comparatively new developments, and seems in many respects to be the best of all, since the liquid is always prepared as a resistance under all circumstances and does not depend upon the energy of the current to make it the imperfect conductor required. Therefore, the disadvantage of the occasional failure of the switch from too rapid or too slow production of the vapor, as is the case with the vapor switch, is avoided. An incident in the difficulty of obtaining the proper switch for high potential working is the difficulty of insulating its moving parts and operating mechanism. Insulation materials of high dielectric strength are not ordinarily satisfactory mechanical materials. They are brittle, they are hard to work, often impossible to work, and are not readily obtained in exact form. Hence, many a switch that is entirely satisfactory from an electrical standpoint proves to be a failure on account of the difficulties with its mechanical support.

Lightning protection for long distance transmission lines is, as one can readily see by the slightest consideration, of the utmost importance. Where a line passes over one hundred or two hundred miles of open country, dipping into the valley and rising to the tops of mountains, all sorts of weather conditions must be constantly encountered. A thunder storm of small area is, in summer time, a matter of frequent occurrence; and when we consider that, as the line stretches way across the country, many small areas of atmospheric disturbances may be and must be daily encountered. To be sure, as you all know, the lightning protection of a transmission line is not against strokes of lightning, but against the induced currents in the line by reason of neighboring lightning strokes. Furthermore, any transmission line must be protected against variation of atmospheric potential in clear weather. Experiments have shown that changes of elevation by a few hundred feet sometimes produce potential variation of many thousand

volts and these phenomena must be encountered and handled by the transmission engineer. One of the most effective devices that has been used is the erection of a continuous lightning rod along the entire line. For this purpose barbed wire, grounded at the poles, has been employed. In some instances this has given trouble on account of the fact that the barbed wire used was inferior in quality and erected with unsafe strains; but when the wire has been carefully erected, it is not necessarily a disturbance to the system, but a means of discharging the wire when the atmospheric potential varies and as induced current surgings are set up by neighboring lightning discharges. It is not by any means a settled principle with transmission engineers to install this barbed wire, though in the South where the lightning disturbances are most frequent, it may be said that almost every line is erected with this protective device. Where it is not used, reliance is placed altogether on the lightning arresters, through which the line may be grounded, these being installed either at the ends of the line or at the ends and at intermediate points; and even where barbed wire is employed, such additional protective devices are absolutely essential, since the circuits themselves can not be entirely freed from induced charges by any means, except enclosing them within a grounded metallic sheath, and this construction would, of course, be absurd and unmechanical. No mechanically operated lightning arresters are ever used for this purpose in alternating long-distance transmission work, the devices employed being either of the non-arcing metal type or of a type where the air current produced by an incipient arc between the parts of the arresters blows out the arc before the machine current has an opportunity of following and affecting destruction. In some devices the combination of these two effects is to be found. These constructions of lightning arrester are old and well tried at lower potentials, but it is found that as the potentials rise, the laws which seem to govern their action change materially, and no step has been made in raising the voltage without requiring material modifications of the rules for the installation of lightning arresters. Two thousand volt calculations have been found to fail altogether on 10,000-volt lines and these again to fail when the potential was raised to 25,000 volts, and finally with the doubling of that potential, the previously ascertained rules seem to be altogether thrown to the winds, and a new system of lightning protection made necessary. The final form in which this will be received by the engineering world has not as yet

been established, but the experiments which have been tried up to the present time, seem to indicate that a resistance or an impedance, or, resistance and impedance combined, must be installed in the path of the ordinary lightning arrester in order to enable the induced charges on the line to pass away readily without noticeably increasing the effective line potential and without grounding and short-circuiting the wires. The handling of this problem has been one of the last to be solved and one of the most troublesome questions involved in the engineering of transmission lines.

I have this evening been endeavoring to call to your minds the problems met by the transmission engineer and the difficulties he has to solve, which are not presented to his brethren in handling ordinary electric lines and currents; and though I may have given you the impression that there are many questions yet to be solved in order to bring about success in long distance transmission, when success is measured by practically perfect regulation and practically absolute continuity, still it would be incorrect for me to have given you the impression that the engineers are still groping in the dark for a solution of their problems for the attainment of success as measured by the criteria I have laid down. The limitations I have placed upon the solutions that have been already applied relate only to the question as to whether present solutions are in their final form, and it would be a wonder of the world if, with long-distance transmission beginning in 1894, with a small plant at Portland, Maine, and a small plant at Housatonic, Massachusetts, the solution that had been reached in 1902 for the problem as extended to 200 miles were in the final form; and if I have given you tonight some of the inside history of the difficulties to be encountered by transmission engineers, you would be doing me and those engineers an injustice to believe that I have been doing anything excepting calling to your attention the difficulties that have been met and the construction which still remains to be improved, while at the same time announcing the triumph in practically and successfully transmitting power up to 215 miles, and practically and successfully building at least, two plants for the permanent distribution of energy at distances in each plant exceeding 150 miles.

THE RECORDED HISTORY OF THE MEMBERS OF THE ARGON GROUP.[1]

By HENRY P. TALBOT.

In his work "On Air," at the opening of the chapter in which he describes the isolation of the gas which we now recognize as oxygen, Priestley writes as follows: "The contents of this section will furnish a very striking illustration of the truth of a remark which I have more than once made in my philosophical writings, and which can hardly be too often repeated, as it tends greatly to encourage philosophical investigations, viz: that more is owing to what we call chance, that is, philosophically speaking, to the observation of events arising from unknown causes, than to any proper design or preconceived theory, in this business."

In 1774 Priestley believed the atmosphere to be a simple, elementary substance, as little destructible or alterable, except as to the admixture of phlogiston, as water was then supposed to be. We learn from Priestley's interesting writings that it was the chance purchase of a burning-lens, and the accidental presence of a lighted candle at an opportune moment which led to the "events," the "unknown cause" of which proved to be the "dephlogisticated air" obtained when mercuric oxide was heated by the concentration of the sun's rays with the aid of the lens. It was only after a long series of experiments that the new gas was recognized to be a constituent, but not the whole, of the atmosphere. The discovery of oxygen was, therefore, not the result of a systematic search.

In the interval of a little over a century between 1774 and 1894 much progress had been made in the accumulation of knowledge regarding the atmosphere, and at the latter date its constituents were regarded as qualitatively and quantitatively established beyond reasonable doubt. But in 1893 one of the "events" referred to by Priestley

[1] Read before the Northeastern Section of the American Chemical Society, February 27, 1902.

occurred, the "unknown cause" of which it became necessary to establish, and it was during the progress of the resulting investigation, as we shall see, that the element which gives its name to the argon group was discovered.

We all remember well the incredulity with which the announcement of this discovery was first met. Hardly since the days of Berzelius, Gay-Lussac, and Davy had there been new elements discovered, save those of rare occurrence in relatively obscure minerals. We were asked all at once to believe that the measurements of the constituents of the atmosphere, made during a century of investigation, had been so faulty that the presence of an element to the amount of about $\frac{1}{100}$ of the atmosphere had been wholly overlooked, and that a substance which we had been taking into our lungs to the amount of 20 liters in each 24 hours, had received no recognition. It is small wonder that chemists everywhere were disposed to be skeptical, and to hold themselves ready to assume a position of general superiority in case the new element proved to be elusive. But the statements then made by Lord Rayleigh and Professor Ramsay have been fully substantiated, and although the discovery of argon was a sort of a by-product from another investigation, we shall see that the discovery of the other elements of this group (except helium) was the result of systematic search, and that the whole investigation was painstaking in the highest degree, and was deservedly rewarded.

The story of the discovery of argon in the atmosphere, which is so pleasantly told in Professor Ramsay's book on the "Gases of the Atmosphere" is doubtless familiar to most of you, at least in its general outlines, but a brief review of this early work will, I feel sure, not be out of place.

In 1893, Lord Rayleigh began a series of determinations of the densities of the principal gases, and in the course of these experiments he made determinations of the density of nitrogen derived from the atmosphere, and of nitrogen derived from such bodies as nitric and nitrous oxides, and ammonium nitrite. The conditions of experimentation were such that he considered his results to be accurate within one ten-thousandth of their value, yet he found that, while the "nitrogen" from the atmosphere contained in his globe weighed on an average 2.3101 grams, the same volume of nitrogen liberated from its compounds weighed only 2.2000 grams, a difference of 11 mgm. in 2 grams, or about one part in two hundred. To confirm these

results subsequent determinations were made using nitrogen prepared from urea, and from ammonium nitrite, without passing the nitrogen over heated metal, in order to eliminate the possibility that the lessening of the density of the chemical nitrogen was in some way due to this heating which was a part of other methods employed; but the figures obtained were in entire agreement with those already noted, and it was further found that if the nitrogen of the atmosphere was absorbed by magnesium at a red heat, and the resulting magnesium nitride afterward decomposed, the nitrogen thus obtained agreed in weight with the chemical nitrogen from its compounds. Beyond any doubt, then, a real difference in density existed, and an explanation must be found. Not being able to supply one himself, Lord Rayleigh asked for the assistance of the chemical fraternity in the solution of his problem.

Suggestions were not lacking! It was said that "the chemical nitrogen contained hydrogen." But it was found that a mixture of hydrogen and atmospheric nitrogen could be separated and the specifically heavier nitrogen isolated, as before. Again, it was suggested that, "the nitrogen had in part polymerized after the fashion of ozone, and that atmospheric nitrogen contained molecules N_3"; or "the chemical nitrogen contained molecules of less size than those with a symbol N_2." Both these suppositions were rendered improbable by the fact that after being subjected to the action of the silent electric discharge, the densities of the two gases differed exactly as they did originally. Moreover, if the nitrogen molecules were dissociated in case of the lighter chemical nitrogen they might reasonably be expected to recombine on long standing; but after eight months the lighter chemical nitrogen persistently retained its lesser gravity.

In short, the probability of the presence in these gases of any known element other than nitrogen, or of the presence of polymeric forms of the element nitrogen itself, was gradually eliminated. There remained, then, only the supposition that there was either an unknown lighter element in the chemical nitrogen, or an unknown heavier element in the atmospheric nitrogen, the latter despite the vast amount of experimentation upon the atmosphere in which chemical literature abounds. The problem was first attacked from the latter standpoint, and Professor Ramsay joined forces with Lord Rayleigh.

The classic experiment of Cavendish was repeated. The atmospheric nitrogen was mixed with oxygen, and subjected to the action

of the electric discharge for some time, the product of the combination being absorbed by caustic alkali. A small unabsorbed residue was always obtained which was proportional to the quantity of air operated upon. It is interesting to note that Cavendish reached exactly this point in his experiments upon nitrogen a century ago. Cavendish remarks that since the small bubble remaining is less than $\frac{1}{120}$ of the bulk of the air used "if there is any part of the phlogisticated air of our atmosphere which differs from the rest and cannot be reduced to nitrous acid, we may safely conclude that it is not more than $\frac{1}{120}$ part of the whole." This small residue obtained by Cavendish did, in all probability, represent what we now recognize to be argon, with minute amounts of other members of the argon group. The determination was nearly quantitatively accurate, and is a striking evidence of the skill of this remarkable experimenter.

Without entering into details of the procedure the results may be summarized in the statement that the residual gas, obtained by long-continued treatment by the Cavendish method, and by another wholly distinct procedure, viz: the repeated circulation of the atmospheric nitrogen over red hot magnesium for a number of days, showed a density of about 19.9 to 20, as compared with hydrogen, and a spectrum in which that of nitrogen was not to be detected, and which was new, characteristic, and uniform in different samples of the gas.

In order to show that this increase in density was not due to any change which the atmospheric nitrogen had undergone during heating, the processes of atmolysis were also employed to concentrate the heavier gas. A number of stems of church-warden tobacco pipes — about twelve — were connected in series, and these were enclosed in a large glass tube, the space between the pipe-stems and the tube being exhausted. At the same time a current, amounting to about 2 per cent. of the total air entering the mouth of the pipe-stems, was drawn out at the other end. It is evident that, in accordance with the law of Graham, under these conditions the gas which failed to be drawn through the pores of the pipe-stems (that is, the portion collected at the open end), should have greater density than that which passes into the vacuous space, provided the atmosphere contained a heavier constituent. In point of fact, the results confirmed the expectations. The air which failed to diffuse through the pores of the pipe-stems had increased materially in density, and after removal of the other constituents (oxygen, water, carbonic acid, and ammonia) the residue was distinctly denser than atmospheric nitrogen.

It was further noted that this heavier residue exhibited a relatively high solubility in water, now known to be about 4 volumes in 100 of water, at 12° C., or about the same as oxygen. Since this is about two and one-half times the solubility of nitrogen the gas expelled by boiling from water which has been exposed to the atmosphere should be relatively dense, or rich in the heavier constituent if atmospheric "nitrogen" is a mixture of these gases. This was found to be true, an increase of 24 milligrams being noted in a weight of 2.3221 grams.

At last, in 1895, Lord Rayleigh and Professor Ramsay felt justified in announcing the discovery of a new element in the atmosphere, to which, on account of its inert character, the name of *argon* was given. The announcement was made at a meeting of the Royal Society in London, on January 31, 1895.

The quantity of argon seemed to be about 1 per cent. of the atmospheric nitrogen, or 0.9 per cent. of the atmosphere. Assuming that the density of argon is 20 — a point to be discussed later — the greater density of atmospheric nitrogen as compared with chemical nitrogen would correspond to this percentage. Later investigations show that argon forms about $\frac{1}{120}$ of the atmosphere by weight and $\frac{1}{125}$ by volume, and that the amount is practically constant. Kellas[1] has claimed to find a somewhat larger amount of argon in respired than in normal air. It has been found in one specimen of meteoric iron, in the waters of a number of mineral springs situated in the Pyrennes, in Wildbad, in the Black Forest, and at Bath, England, and in the gas which escapes in bubbles at one or two springs in France. It has also been found in the gases occluded in rock salt, and as a constituent of fire-damp at Rochbelle.

It has not yet been found to be a constituent of either animal or vegetable matter, at least as far as these are typified by mice and peas. It has been found to be a part of the gas found in the air bladder of fishes.

Argon, as originally derived from the atmosphere, did contain other gases, as will presently be shown, but after the removal of these gases, the residue seems to be an elementary substance, and one not previously known, although articles still appear in which it is claimed that argon is a polymer of nitrogen. This idea finds confirmation only in the fact that many lines of the spectra of the two gases lie very near together, and the fact that if this were true, argon would

[1] Proc. Roy. Soc., 59, 66.

possibly fit better into the periodic system. On the other hand, in no case has it been possible to detect anything corresponding to argon in nitrogen from chemical sources; the density, as will be seen, does not correspond with accuracy to N_2; and the existence of other members of a group in which argon seems to have a logical position appears to confirm its independent existence.

The chemical properties of argon seem capable of expression in a most concise form. It has no chemical properties. In one of the earliest papers, the following statement was made regarding the attempt of Rayleigh and Ramsay to discover some reaction into which argon would enter: "Argon does not combine with oxygen in presence of alkali under the influence of the electric discharge, nor with hydrogen in presence of acid or alkali, nor when sparked; nor with chlorine dry or moist, nor when sparked; nor with phosphorus at a bright red heat; nor with sulphur. Tellurium may be distilled in it; also sodium and potassium. Red hot sodium peroxide has no effect. Persulphides of sodium and calcium have no effect at a red heat. Platinum sponge does not absorb it. Aqua regia, bromine water, bromine and alkali, and potassium permanganate are all without influence. Mixtures of metallic sodium and silica, or sodium and boric acid are without influence, hence also nascent silicon and boron.

Moissan [1] has experimented with argon and fluorine at high and low temperatures and finds no action, nor is there any action upon titanium, boron, lithium, or uranium at high temperatures.

Ramsay at one time thought that he had effected a combination with carbon at the temperature of the electric arc, but it subsequently proved that the expansion observed was due to the carbonic acid occluded on the carbon rods. He found no action with carbon tetrachloride.

The literature contains accounts of a few experiments which have, temporarily at least, been assumed to indicate that argon had been persuaded to combine with certain elements or radicals. These include the considerable series of experiments made by Berthelot, [2] in which he mixed argon with the vapor of benzene, carbon bisulphide, and a number of other substances belonging to both the fat and aromatic series of organic compounds, and subjected the mixture to prolonged action

[1] C. R., 120, 666.

[2] Described in C. R., 120, 121 and 129.

of the silent electric discharge. In the case of benzene he observed a diminution of volume of the gas and the formation of a brown substance, which exhibited a brilliant green fluorescence and spectrum. The quantity formed was too small for further investigation, and the evidence of actual combination is not conclusive. Ramsay was unable to obtain parallel results, and other investigators have pointed out that the green spectrum is very likely due to the presence of mercury vapor from the pump. Berthelot has later contended that the compound producing the fluorescence contains mercury and the phenyl group, but here, again, his experiments with the phenyl-mercury compounds are not wholly convincing. It should be added, however, that he finds something of a uniformity of behavior among a number of the benzene compounds which he examined, while the members of the methane series are uninfluenced by the same treatment.

Troost and Ouvrard [1] made the statement that they had effected a combination of argon and magnesium. This is based upon their observation that if magnesium is introduced into a vacuum tube containing a very small amount of argon, the spectrum of argon gradually disappears, and they conclude that it is absorbed by the magnesium, or combines with its vapor. It is not impossible that if platinum electrodes were used here, the platinum, rather than the magnesium, absorbed the small quantity of the gas on its surface.

Villard [2] finds that under a compression of 150 atmospheres, in the presence of water at 0°C., argon forms a crystalline hydrate, which readily dissociates at a pressure of 105 atmospheres. The presence of argon in the crystals was not proven, but the author judges from analogous behavior of nitrogen and oxygen that they contain argon.

The complete lack of chemical data concerning this unique element lends special interest to the study of its physical characteristics. Of these three are of special importance — its spectrum, its specific gravity, and the atomicity of its molecule.

The spectrum of argon, at 3 mm. pressure, shows a great number of lines over a very wide field. Two red lines less refrangible than those of hydrogen or lithium, a yellow line more refrangible than sodium, a group of five green lines, a blue line, and a group of five violet lines make up the principal part of the collection. The spectrum undergoes

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[1] *C. R.*, 121, 394.

[2] *C. R.*, 123, 377.

a striking change when the nature of the discharge is altered. With an intermittent discharge the glow is red, with an oscillatory discharge the glow is bright blue, and many new green and blue lines appear. With a Tesla discharge the glow becomes nearly white, but the spectrum is similar to the blue spectrum, while by passing an alternating current of low voltage through the primary circuit of the induction coil, a peculiar spectrum is produced in which certain red lines are particularly pronounced. Crookes states that the spectrum from the blue glow shows 119 lines, while that from the red glow shows 80 lines, and 26 of these appear to be common to both spectra.

These variations have been made the basis of arguments against the elementary character of argon, but it should be noted that nitrogen also gives a double spectrum according to the character of the induction current.

Hartley[1] points out that since all known compounds are decomposed at the temperature of the electric spark and since its spectrum shows no familiar lines, argon, if a compound, must be made up of elements all of which are as yet unknown.

The density of argon is of the greatest interest, and has been most carefully studied. Ramsay has made repeated determinations of the density of the gas after repeated purification, the separation from the other members of the group being so complete that no evidence of their presence was indicated by the spectroscope. These determinations were accomplished by direct weighings in globes of known capacity, varying from 30 c.c. to 160 c.c. The best results seem to point to 19.96 as being the true value for the density of the gas, which corresponds to a molecular weight of 39.92 ($O = 16$).

What, then, is the atomic weight of argon? This question assumes prime importance, since upon it depends the relation of this new element to the other members of the periodic system of Mendelejeff. It was early determined that the ratio of the specific heat of argon at constant pressure, to the specific heat at constant volume, is 1.61 to 1.65. As is well known, this is the ratio which, from theoretical considerations, is assumed to correspond to a monatomic molecule, in which the whole of the heat-energy is converted into translatory motion. Repeated experiments have confirmed this value for the ratio of the specific heats, and the conclusion seems to be — if the premises are

[1] *Chem. News*, 74 209.

sound — that argon is a monatomic gas, that its molecular weight and atomic weight coincide, and that this value is 39.92. Incidentally this evidence may be said to point to the elementary character of argon, since it is improbable that a compound substance would exhibit this behavior with respect to the utilization of all the energy for translatory motion. It does not, however, necessarily preclude the presence in the argon of other monatomic elementary molecules. These points will be touched upon again.

It is of interest to note that lithium will remove nitrogen from argon with rapidity, and that metallic calcium formed from a mixture of anhydrous calcium oxide and metallic magnesium also removes the nitrogen with greater promptness than magnesium alone. The lime must be as dry as possible, otherwise explosions ensue, and even under great precautions some hydrogen is usually mixed with the argon, due to the action of the traces of moisture on the magnesium. This process is used in the preparation of argon in quantity.

The other important properties of argon are given in the table on page 227.

Helium.

In 1868, while examining the spectrum of the chromosphere during an eclipse, Jannsen noted a brilliant yellow line which was close to, but not identical with, the well-known D-line of sodium. This he designated as the D_3-line, and in the same year Lockyer assigned the name "Helium" to the hypothetical element of which this line was characteristic. Since that date the line has often been observed without the conditions which accompany an eclipse, by projecting the image of the edge of the sun on the slit of a spectroscope of wide dispersion. The D_3-line is also found in the spectrum of the corona and in that of some of the fixed stars and nebulas.

In 1882, Palmieri stated that he had discovered helium in a substance which is found with the lava of Vesuvius; but it appears that he did not attempt to isolate the helium, merely observing the spectrum of some body which gave a line corresponding to the D_3-line. It is not improbable that he was correct in his suspicions, although his proof is incomplete. Such was the knowledge of helium up to 1895.

After the discovery of argon, and the announcement of its inert character, Mr. Myers, the mineralogist of the British Museum, wrote to

Professor Ramsay calling his attention to the fact that cleveite, (a uranate of lead, thorium and uranium) had been shown by Hillebrand to contain nitrogen, and offering the suggestion that this mineral might also contain argon, or that some of its constituents might prove to be capable of entering into reaction with the inert gas. The suggestion was adopted by Professor Ramsay, and, after some months of delay as a result of his investigations in other branches of research, he obtained a quantity of cleveite, and examined the gas which was liberated from it by treatment with sulphuric acid, subjecting it to the methods of purification from nitrogen already spoken of in connection with argon. When subjected to spectrum analysis the residual gas showed argon, to be sure, but it also showed a new series of lines in the red, green, blue, and violet, and notably a brilliant yellow line. At this time, however, Ramsay was employing magnesium electrodes in his vacuum tubes, in the hope of thus absorbing any residue of nitrogen, and as the metallic magnesium had been reduced from its compounds by means of sodium, he attributed the yellow line to a small amount of the latter metal which had been volatilized. But on careful examination he was surprised to find that he had two bright yellow lines very close together, — but still distinct. He soon determined to send the gas to Crookes for examination, and Crookes at once reported by telegraph that helium could no longer be counted as among the extra-terrestrial elements. The yellow line was the D_3-line with a wave-length of 5875.9. The D_1-line is located at 5896.1 on the same scale. Experiments then made gave 3.89 as the maximum density of the gas, and the ratio of the specific heats was found to approximate 1.66. The gas is, then, as was to be expected from its existence in the chromosphere, very light, and it appears to be monatomic.

All the minerals in which Hillebrand had found nitrogen contained uranium. Ramsay examined not alone such minerals, but a great many substances of varying composition, by heating them in an exhausted tube, taking care to prevent the admission of carbonic acid or moisture. It was incidentally found that many minerals gave off hydrogen, and it was shown quantitatively that this hydrogen results from the action of water on oxidizable constituents of the minerals, such as ferrous compounds.

The helium may be liberated from the minerals by heat alone, by treatment with sulphuric acid, or by treatment with acid potassium sulphate. Under the influence of heat alone, the gas begins to be evolved at about 200°, and the evolution becomes rapid at a red heat,

but the total amount obtained is approximately half that liberated by sulphuric acid. The decomposition by means of acid often requires a number of days for completion; that by acid sulphate is more rapid, but the decomposition of the mineral is never complete.

Ramsay preferred the use of heat alone, and his procedure was the following: The tube containing the mineral was exhausted as completely as possible before heating. The gas evolved from the mineral was pumped out of the tube and was first passed through a solution of caustic soda to remove carbonic acid, then mixed with oxygen and sparked to remove hydrogen and hydrocarbons, then treated again with caustic soda; finally the gas was mixed with oxygen and exposed for several hours to an electric discharge to remove nitrogen. The residue is argon and helium with some oxygen, which is afterward removed by phosphorus. For the examination of the spectrum a Plücker tube was exhausted and one or two bubbles of the gas were admitted, after passage over phosphorus pentoxide. Aluminum electrodes were used, and at the temperatures produced by the current these absorb the residual nitrogen or hydrocarbons, and the spectra of argon and helium only remain. In this way he examined fifty-one minerals, and found helium in sixteen. Lockyer examined sixty-five, and found helium in fifteen; his method is, however, a little less accurate than that of Ramsay.

The fact is important that all minerals furnishing more than a trace of helium contain uranium, yttrium, or thorium, or a mixture of the three. Malacon, which yields argon and helium (the former in excess), is a hydrated silicate of zirconium. It is the only mineral which gives argon, in notable quantity, without containing uranium.

The amounts of helium varied greatly. A sample of uranite gave 13.5 c.c. per gram, a sample of cleveite yielded 6.1 c.c. per gram, a sample of broggerite furnished 1.8 c.c. per gram, while many yielded only a trace of the gas.

The question must, of course, at once arise: Is helium in solution, in combination, or occluded in these minerals? The evidence afforded by the experimental data at hand is conflicting. An examination of the gas which is evolved on heating a specimen of broggerite shows that it contains almost no free hydrogen, and no combination of helium and hydrogen could be detected in it. There is, moreover, no constant relation between the amounts of helium and hydrogen evolved when the minerals are treated with acid, hydrogen being absent in some cases.

On the other hand, Tilden allowed cleveite to remain for some time at 100° C. under a pressure of seven atmospheres, in contact with the gas which had been evolved from the mineral, and states that a small quantity of the gas was reabsorbed, indicating a recombination of the helium. Ramsay, however, operating at atmospheric pressure, was unable to confirm Tilden's results, and the evidence is accordingly less convincing.

Finally, there is the evidence afforded by the experiments upon fergusonite and yttrocerite. Fergusonite is a transparent mineral, which under the microscope shows no trace of crystalline structure; it is perfectly homogeneous and shows no bubbles (interstices). But on heating to 500° it becomes incandescent, and gives up most of its helium. The density falls from 5.619 to 5.375. There are other minerals which evolve heat under similar circumstances, but they do not become incandescent, and either yield no helium, or only a trace, and their densities are greater after than before the heating. By means of calorimetric measurements four fairly concordant values for the heat of incandescence have, however, been found to approximate 809 cal. per gram, and this would seem to show that helium forms a true compound with some constituent of the fergusonite, the heat evolved being that of decomposition at the moment of the liberation of the helium. These results are confirmed by Thomsen's experiments [1] with yttrocerite which also becomes incandescent upon heating, and evolves helium.

From the foregoing it is evident that the question of the state in which the helium exists in these minerals cannot be finally answered, but the positive evidence seems to slightly outweigh the negative and to point to a possible combination with some constituent of the minerals examined.

Helium has been found in one sample of meteoric iron, together with argon, but was absent from other samples examined. It was found in the gases issuing from the springs at Bath, England (forming 1.2 per cent. of the gas), and at some other points, but not by any means in all the gases examined. It has only been found in gases emanating from *hot* springs.

For some time it was a point in doubt whether helium is a constituent of the atmosphere. Kayser [2] and Friedländer,[3] working inde-

[1] *Zeitschr. phys. Chem.*, 25, 112.

[2] *Chem. News*, 72, 89.

[3] *Zeitschr. phys. Chem.*, 19, 657.

pendently, claimed to find it, but Rayleigh and Ramsay were unable to detect it. When, however, large quantities of liquid air were worked over in the search for the possible companions of argon, it was soon found that helium was beyond question present in the earth's atmospheric envelope.

The preparation of helium in large quantities in a state of purity has proven to be a matter of grave difficulty, on account of the fact that the gas must be handled over mercury in order to prevent contamination by argon, which, on account of the chemical inertness of both substances, can only be separated by means of fractional diffusion or fractional distillation, both of which are extremely tedious procedures. A separation based upon the difference in solubility in water, is possible up to a certain point, but cannot be made complete.

The sources of helium are liquid air and certain minerals, the latter being probably the more available source. To obtain the helium, the minerals are heated in a hard glass tube which has been carefully exhausted by means of a Töpler pump. The gas evolved is collected over mercury, and is then passed over caustic soda to remove carbonic acid, over heated cupric oxide to remove hydrogen, over heated magnesium to remove nitrogen, and over phosphorus pentoxide to remove water. The hydrocarbons are, of course, removed at the same time with the hydrogen.

The most accurate results in the determination of the density of helium seem to place the value at 1.99. The ratio of the specific heats has been found to be 1.65, which indicates that the atomic weight of helium is 3.98.

Dewar at first supposed that he had liquefied helium at the temperature of melting hydrogen, about —260°, but subsequent experiments failed to confirm this, and it is now considered that helium is the only gas which has not been liquefied, and that its boiling-point lies below that of hydrogen, being probably about 5° absolute, a fact which is confirmatory of its monatomic character. Repeated diffusion experiments failed to give any data which would indicate that helium is other than an elementary substance. Fractions varying slightly in density were, indeed, obtained, but they showed absolutely no spectrum lines except those of helium and argon.

Estreicher[1] finds that the solubility of helium in water decreases

[1] *Zeitschr. phys. Chem.*, 31, 176.

from 0 to 25° C., and then increases. Its solubility is very small at first, but at 30° it is about equal to that of nitrogen. He points out that the curve showing the solubility of hydrogen, the next lighter gas, also possesses a minimum point, and thinks that the same would be true of all gases if their solubilities were studied at higher temperatures. The very slight solubility of helium corresponds with its resistance to liquefication.

The rate of diffusion of helium seems to be a little greater than would correspond with its density as determined by weighing. It conducts electricity with extraordinary readiness, as is shown in the tables below, which give the distances at which a spark will pass between electrodes in different gases at a constant potential, and also the pressure at which a spark discharge changes to a luminous band.

LENGTH OF SPARK (UNDER SAME POTENTIAL).

	MILLIMETERS.
Oxygen	23.
Air	33.
Hydrogen	39.
Argon	45.5
Helium	150–300.

GAS PRESSURE AT WHICH SPARK DISCHARGE CHANGES TO BAND DISCHARGE.

	MILLIMETERS.
Air	73–74
Hydrogen	42–43
Oxygen	81
Carbonic Anhydride	92–94
Cyanogen	23
Nitrogen	33
Carbonic Oxide	49
Helium	1270

Ramsay calls attention to the fact that the low index of refraction of helium (0.1245), the high rate of diffusion and electrical conductivity, all point to small molecules occupying very little space, and moving with great freedom and rapidity.

Helium appears to be as inert as argon under the conditions of experimentation. In the attempt to study the chemical activity of helium, the gas was passed through a hard glass tube containing the substance which was to be tested, and the gas remained in contact with it for at least one-half hour, under such conditions that a change in volume of 2 or 3 c.c. could easily have been detected. The tube was afterward cooled, and the gas removed by the pump. The results were negative in every instance. The substances tested were similar to those enumerated under argon.

Helium is apparently slowly absorbed by platinum when the platinum is spattered on the walls of the vacuum tube; but this is true only to a small extent, and the nature of the absorbent action is still obscure. Ramsay suggests that Berthelot's results with benzene in the case of argon and helium may be of a similar character.

The spectrum of helium is exceptionally beautiful, showing lines in the red, yellow, green, and blue of marked brilliancy. Lockyer was inclined to believe that the spectrum attributed to helium was really that of more than one element, basing his belief upon the fact that the spectra given by the fixed stars varied somewhat, and did not always exhibit all the important lines. Ramsay, in reply to this statement, expresses his conviction that variations of distance, temperature, and other conditions may very well occasion the observed fluctuation in the spectra, and does not consider that this evidence can outweigh the fact that no differences of density can be detected by careful diffusion experiments with helium.

A contention of Runge and Paschen[1] that helium comprised at least two elements deserves consideration on account of the general acceptance which was for a time accorded it. These observers found that the lines of the spectrum of helium could be divided into two sets, and that each set consisted of a primary and two secondary series of lines, of which the vibration frequencies could be expressed by a logarithmic formula. This they attributed to the presence of two gases, and gave to the lighter gas — that is, to the one with its spec-

[1] *Math. nat. Mitt.*, (Berlin) 1895, 323.

trum nearer the violet end — the name "par-helium," and to the other "helium." The former exhibited a spectrum in which the green line was very pronounced, while the latter gave the characteristic yellow line. Their observations seemed to be confirmed by the fact that if helium was allowed to partially diffuse through a porous plug, the gas which diffused showed a green glow, and the bright green line.

This fact that the helium spectrum contains two sets of lines of which one comes into prominence at one time, and the other predominates at another time has not been explained but it has been shown that mere change of pressure in the vacuum tube will occasion this variation, and it has also been shown that similar conditions exist in connection with oxygen, and if these facts are to serve as arguments for the dual character of the gas in one case, they must in the other.

Additional evidence of the simple character of helium is found in the fact that helium is partially absorbed by the platinum spattered on the sides of the vacuum tubes, and as this absorption progresses, the glow changes from yellow to green. If this indicated the removal of one constituent of a mixture the spectrum of the gas liberated from the platinum should show the yellow line without the green line, or the latter should at least be weak. In fact, the liberated gas shows the same behavior as the original gas from cleveite.

The properties of helium are stated in the table on page 227. It is also worthy of note that helium shows little variation from the gas laws, and is therefore of value for use in thermometers, especially at low temperatures. It has been used to measure the boiling and freezing point of hydrogen.

Discovery of Other Members of the Group.

In December, 1898, Professor Ramsay, in a lecture before the *Deutsche Chemische Gesellschaft*, gave an account of the steps which led to the discovery of the other members of this unusual group. The fact has already been mentioned in connection with both argon and helium that their molecules appear to be monatomic, if we accept as conclusive the evidence furnished by the ratios of their specific heats at constant pressure and constant volume. Some doubts to be mentioned later have been raised as to the validity of this proof because of the conflicting arguments to be brought forward from the point of view of the periodic system. If argon has an atomic weight 40, then, as we shall later see, it does not fit into that system, since this would place it

between potassium and calcium. On the other hand, the assumption that the atomic weight of helium is 2 instead of 4, while less troublesome, is still open to objection. Chemical evidence by which to determine these points is, of course, lacking. Ramsay states that while he preferred to accept the physical proof of the monatomic character of the two elements, leaving their exact relations to the rest of the periodic system for later settlement, he also determined to attack the problem from a standpoint based upon the general relationship of these elements to that system.

He pointed out that if the atomic weights were assumed to be 2 and 20 there would be no place for an element of this group between argon and helium, since each pair of the elements in the various groups in this portion of the system shows a uniform difference of about 16 or 18 in atomic weights. On the other hand, if the atomic weights 4 and 40 are assumed to represent the truth, then there is a space to be filled by an element with an atomic weight about 16 higher than helium, and 20 less than argon. He pointed out that the discovery of such an element would not only be confirmatory of the atomic weight 40 for argon, but also of the significance of the specific heats of gases as a criterion of their molecular weights. He accordingly began at once a search for such an element.

This quest, begun by Ramsay and Collie and continued by Ramsay and Travers, opened with the careful examination of the same minerals which had proved to be a source of helium, as well as a considerable number of other minerals of different chemical character. The results were, however, entirely negative. Helium was found in a number of minerals, in one or two argon was present in small amounts, but in no case could lines be detected by the spectroscope which were not characteristic of known elements. Meteorites next received attention, but of seven of these, one only gave a little helium and a trace of argon. The gases from mineral springs were alike unproductive.

At this stage the search appeared to be in a high degree discouraging. One hope remained however. The atomic weight of argon would be more tractable if it could be reduced below 40, and a search after a constituent of the atmosphere having a lesser density than 20 seemed worth the making, in view of these considerations: first, that Dr. Johnstone Stoney had made a statement, based upon calculations, that while an element as light as helium could not probably be retained in the earth's atmosphere, an element having a density of 9 or greater,

would probably be so held; and second, because in the diffusion experiments in the purification of argon a single portion of gas of lesser density had been obtained, but, as at that time helium and its sources seemed a more promising field, this clue had not been followed up.

It was next determined to work upon large quantities of argon, studying it in the liquid condition. Some months were required for its preparation, special tubes, furnaces and gas holders being necessary.

The oxygen was removed from the air by means of phosphorus, until about 200 liters of atmospheric nitrogen were collected. This was dried by sulphuric acid and phosphoric anhydride. Then the gas was repeatedly passed over magnesium at a red heat, to remove nitrogen; then over copper to remove hydrogen, the water being again absorbed as before. For the final removal of nitrogen, the gas was passed over a mixture of lime and magnesium at a red heat; then over copper oxide again, to remove hydrogen, as the lime could not be entirely freed from water. In connection with this procedure, the question whether the gas sought for could possibly remain in combination with the magnesium was investigated. The magnesium nitride was decomposed, but only ammonia, hydrogen, and a trace of hydrocarbons were found. The nitrogen from the ammonia was found to be identical with nitrogen from nitrites, etc. The examination of the residual magnesia (after treatment of the nitride) was not completed, as other lines of work developed positive results at that time.

In preparation for the liquefaction of the argon, Ramsay and Travers made some preliminary experiments with liquid air simply to acquire facility in manipulation. In the course of these, Ramsay remarked that it seemed a pity to have the liquid air boil away without examining the last fraction as to its character. This residue was collected, and after removal of the oxygen — of which, with argon, it was chiefly composed — and of the nitrogen, it was found that there were present new spectrum lines, notably a yellow line not identical with that of helium, and a new green line. The gas had a density 22.5 instead of 20, and again the ratio of specific heats of the mixture of gases was found to closely approximate 1.66. Here then was a new element, or elements, but not the one sought for. Ramsay, assuming the presence of one only, gave the name "krypton" (concealed) to it; of its properties more will presently be said.

Ramsay then proceeded to liquefy the argon which he had purified. It yielded 25 c.c. of a clear colorless liquid, containing flocks of a

white solid. By increasing the pressure on the liquid air surrounding the argon (it was first reduced to 10-15 mm.) the temperature slowly rose, and the argon began to boil. A first fraction was collected separately, then the major portion of the gas was allowed to return to the gas holder; a final portion was again collected separately. A solid substance remained with some persistence, but gradually evaporated when the vessel was connected with a Töpler pump.

The light fraction was first examined. Its density was 14.67; the ratio of specific heats, 1.66; the spectrum showed, beside the lines of argon, a number of new lines of red, orange, and yellow of marked brilliancy. Here again was a new element or elements. The process of liquefaction was again applied to this gas, but this time not all could be made to liquefy at temperatures obtainable by liquid air, even after repeated attempts with the gas under an atmosphere's pressure. This non-condensible gas was separated and again examined. The density, to the great satisfaction of the investigators, was found to be 9.76. Some argon was, however, still present. The new gas, which was designated as "neon," would then, when pure, probably have a density lower than 9.76. But later spectroscopic examination showed the presence of helium, which, on the contrary, would decrease the density of the mixture.

The next problem was how to remove these elements, argon and helium. How this problem was solved will be explained in a moment. It suffices here to say that neon proved to be the missing member of the helium-neon-argon triad for which Ramsay was seeking.

In the address already referred to, Ramsay stated that they had not had time to investigate the other components of the less volatile portions of the "argon," but they considered that it contained at least three gases, — two beside krypton and argon. One of these they named "xenon" (stranger), but at that time they obtained it only in an impure condition, studying its spectrum, and determining its density as 40.5 to 41.1. Of this also more will be said later.

The fourth component of the less volatile portion was given the name "metargon." It was at that time a source of much perplexity to the investigators, and its spectrum was found to resemble the so-called "swan spectrum" of carbon monoxide. Subsequent study showed that the supposed new element was in reality carbon monoxide, which had been, as it proved, introduced by the presence of carbon in the phosphorus employed to remove the oxygen from the original air. This

was not suspected by the investigators, and caused no little annoyance and labor. It is a striking example of the difficulties which beset investigators, and of how the most careful observers may be temporarily led astray. "Metargon" must, then, be dropped from the list of the newly identified elements.

To determine how far the density of argon was influenced by the presence of these other gases, 25 c.c. of fluid argon was fractionated three times — 200 c.c. of the most volatile and 200 c.c. of the least volatile portions of the gas being separated each time. Then the middle portion was liquefied, and on evaporation, six fractions were collected and examined. The densities are given in the table:

	Density.	Refractivity.
1.	19 65	0.962
2.	19 95	0.969
3.	19 95	—
4.	19.91 (subsequently 19.96)	—
5.	19.97	0.968
6.	19.95	0.966

Of the newer elements only neon is present in sufficient amount to appreciably influence the density of argon, and then only in the second decimal. Xenon could not be detected at all in 15 liters of argon gas.

The latest results place the amounts of these elements in the atmosphere at approximately the following figures:

Helium	1 to 2	parts	per	million
Neon	1 to 2	"	"	hundred thousand
Argon	0.937	"	"	hundred
Krypton	1	"	"	million
Xenon	1/20	"	"	million

It seems probable, according to Stoney, that helium continually passes out of the atmosphere, owing to its lightness, but in the aggregate the amount issuing from mineral springs is enormous, and maintains the proportion in the atmosphere at a constant quantity.

The methods employed to separate helium, neon, krypton, and

xenon from argon and from each other deserve brief consideration. A detailed description of the fractionation processes is to be found in the recent volume by Travers, entitled, "The Experimental Study of Gases." Only an outline of the essential features will be given here.

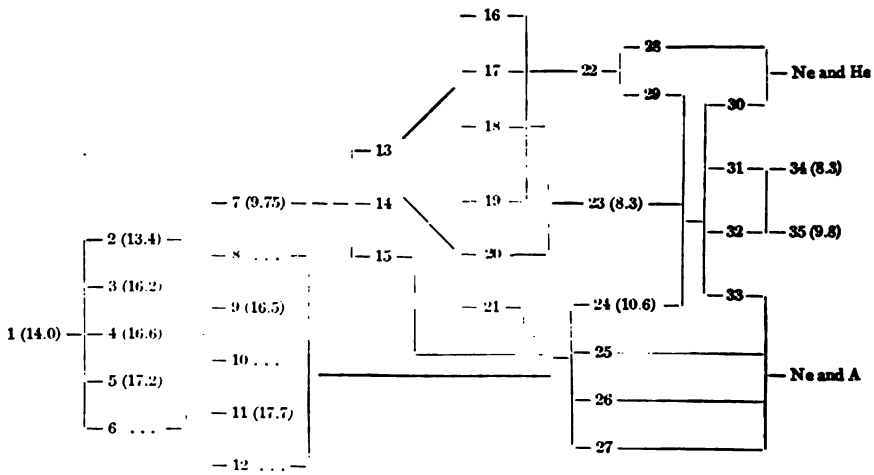
The spectroscope was first used to test the purity of the gases and to note the progress of the separation, but it was found that this instrument would not show traces of one gas in another, as is evident from the table given below based upon a statement made by Ramsay. As an ultimate test of the impurity or purity of the gases it was therefore found necessary to resort to repeated determinations of density, with intermediate diffusion or fractionation. If successive weighings under these conditions gave constant results, the gas was considered to be pure. It was found possible to obtain accurate determinations of density by using a globe of 7 c.c. capacity if the weighings were completed to one one-hundredth of a milligram.

PER CENT BY VOLUME OF GAS CAPABLE OF DETECTION BY MEANS OF THE SPECTROSCOPE IN MIXTURES:

GASES.	PER CENT.
Helium in Hydrogen	10.
Hydrogen in Helium	.001
Nitrogen in Helium	.01
Helium in Nitrogen.	10.
Argon in Helium	.06
Helium in Argon	Over 25 at 0.58 mm. pressure
Nitrogen in Argon	" .08 at 0.18 mm. pressure
Argon in Nitrogen	37.
Argon in Oxygen	2.3

The process of fractionation was as follows: The gas was passed from the gas-holder into an apparatus provided with a small bulb surrounded by liquid air, the air being made to boil at a pressure of a few millimeters. At this temperature the gas condensed to a liquid. By increasing the pressure upon the liquid air its boiling-point was raised, and the liquid within the bulb distilled slowly. The gases thus liberated were allowed to pass into gas-holders, these holders being

changed just as the receivers are changed during the fractional distillation of a mixture which is liquid at ordinary temperatures. The gas was pumped out of the bulb into the gas-holder at the end of the operation, or at other times, when necessary. After the liquid had completely evaporated and had thus been divided into fractions, these fractions were recondensed in turn and allowed to evaporate and were thus refractionated. In this process the less volatile portion of the first fraction introduced is recondensed with the second fraction, and so on. For the separation of argon, neon and helium, the *heaviest* fraction was first recondensed, and to the residue from this the next lighter was added, and so on, while to separate the gases which are heavier than argon, the *lightest* fraction was first recondensed, then the next heavier, and so on. The scheme of fractionation given below illustrates the procedure in the attempt to isolate neon. The numbers in parentheses represent densities.



As it was found that fraction No. 7 could not be condensed even under pressure at a temperature obtainable with liquid air, it was necessary to mix the gas with a considerable quantity of oxygen and to continue the fractionation of this mixture. The oxygen was removed before determining the density of the fractions. In this way the separation was carried to the point indicated in the scheme, but the helium could not be separated from the neon, and the volume of the mixture of the two had been reduced so low that further work was impossible until a larger quantity of [illegible] was available. In the preparation of this,

Ramsay and Travers made use of the fractionation principle in the initial preparation of liquid air. A considerable portion of air was liquefied, and then a small portion of this was allowed to distil, which was then transferred to the compression apparatus and re-liquefied with new portions of air. By repeating this procedure, they ultimately obtained about 120 liters of air which was distinctly lighter than common air, and from this, after removal of oxygen and nitrogen, about 800 c.c. of argon which was comparatively rich in neon.

It is interesting to note that it is necessary to agitate the liquid air during distillation in order to obtain the neon. Unless this is done the evaporation takes place from the surface of the liquid only, and the first product is mostly nitrogen and argon. This is said to be due to the fact that the nitrogen becomes superheated.

With this new quantity of argon, neon, and helium, the fractionation processes were repeated, as already described, and nitrogen was substituted for oxygen, but without improvement. A point was reached beyond which the separation could not be carried by this means. The densities varied from 7.24 to 8.27.

Diffusion methods were next tried, but were only partially successful, although the density increased to 9.18, with no evidence of argon.

"The separation of these two gases was ultimately accomplished by liquefying them in a bulb cooled by liquid hydrogen. At this temperature the neon condensed, possibly to a solid, and its vapor pressure was not more than 50 mm.; the helium appeared to remain gaseous, while the argon was non-volatile. After condensing the gas the first fraction was taken into the pump; it contained a large quantity of helium. The second fraction, which evaporated slowly, was collected separately, and after removing the vacuum-vessel containing the hydrogen, a third fraction containing argon was collected. The second fraction was then recondensed, a small quantity of it was allowed to evaporate into the pump, and the main bulk of the gas was collected as pure neon; the last traces of the gas were again discarded, since they might contain traces of argon.

The fraction of the gas supposed to be pure neon was found to have the density 10."

The separation of krypton and neon from argon and from each other, was only effected by a long series of fractionations, involving the utmost patience and a high degree of manipulative skill. A large quantity of liquid air was allowed to evaporate quietly, and the less

volatile portions were collected and freed from oxygen and nitrogen as already mentioned. The residual gas had a density 22.5 — a value somewhat greater than that of argon. The investigators were surprised to find that the density of the fraction which was supposed to contain the heavier krypton was less than that of the initial gas, although it showed the krypton lines. An explanation of this was subsequently found in the low vapor pressure of xenon at the temperature of liquid air which caused it to be held back in the bulb. This property of xenon was ultimately utilized to separate it from krypton.

The scheme of fractionation is similar to that noted for the separation of the lighter gases. After the argon had been practically separated, it was found that xenon solidified at the temperature of liquid air, while krypton had a vapor pressure of about 150 mm. It was therefore necessary to remove the krypton from the fractionation bulb by means of a pump. The separation of xenon and krypton, (which was more tedious than difficult) was retarded by the fact that the latter seemed to be enclosed in, or to be soluble in, the solid xenon. It was finally possible for Ramsay and Travers to isolate about 16 c.c. of a gas which withstood their tests for purity, and which they regarded as pure krypton. The amount of xenon isolated was about 3 c.c. The former gas had a density 40.75; the latter, 64. In both cases, the ratio between the specific heats is approximately 1.66, indicating molecular weights of 81.5 and 128, respectively. The remaining properties are stated in the table on page 227. The spectrum of krypton is easily detected in the presence of other gases; the spectra of krypton and xenon undergo a corresponding change to that of argon when the character of the electric discharge changes.

So far as is now known, all of these elements are as inert chemically as argon.

Since the completion of the work of Ramsay and Travers, Ladenburg and Krügel[1] have prepared a fresh quantity of krypton, starting with 850 liters of liquid air. From this they obtained about 3 liters of the less volatile residues, which gave about 3.5 liters of gas after the removal of the oxygen and nitrogen. This was condensed, the argon removed by fractionation, and finally a crystalline solid was obtained, from which by fractional evaporation they obtained a gas which appeared to be of constant composition, showed the krypton

[1] *Kgl. Akad. Wiss. Berlin* (1900), **16**, 212 and 727.

lines with brilliancy, and after repeated fractionation the fractions showed densities of 29.33, 29.50 and 29.40, from which they conclude that the atomic weight of krypton is about 59 instead of 80, as determined by Ramsay. Although this work was published in 1900, Ramsay appears to have made no comment upon it and Travers does not mention it in his book recently issued. Its bearing upon the question of the position of these elements in the periodic system will be discussed presently.

Liveing and Dewar[1] have recently made an interesting study of the most volatile and the least volatile gases of the atmosphere which merits a moment's attention. They collected about 200 c.c. of liquid air from the roof of a building in London, cooled it to —200° C., and then allowed the more volatile portions to distil into a vessel cooled to —210° by liquid hydrogen. The liquid then condensed to a solid. When the equivalent of 10 c.c. of liquid had solidified, it was allowed to evaporate and passed into vacuum tubes through a tube surrounded by liquid hydrogen, which condensed all but the most volatile gases. The spectrum showed helium, neon, and hydrogen, and some new lines which may belong to these elements, or may represent bodies as yet unidentified; on this point they withold a positive statement. They searched for lines corresponding to those found in the spectrum of the corona, aurora, and nebulas, but while they found close approximations to these lines, they could not state positively that the correspondence was complete.

A most interesting outcome of this work was the discovery that hydrogen is present in the atmosphere. When the tube surrounded by liquid hydrogen between the distilling gas and the vacuum tube was omitted, the gas was found to contain very considerable quantities of hydrogen. In view of Dr. Johnstone Stoney's statements that helium cannot be retained in the atmosphere of the earth, this discovery raises a number of interesting questions, — among others, what is the source of this hydrogen?

For the examination of the *least* volatile gases, the residual portions of the liquid air were condensed to a solid by the aid of liquid hydrogen, and it was found that by slowly raising the temperature of the solid the components gradually evaporated, and that the change from one to the other was surprisingly sharp. By means of a sparking tube

[1] *Proc. Roy. Soc.*, **67**, 467 and **68**, 392.

through which these gases passed, the progress of the separation could be accurately followed. They found that the spectra of both krypton and xenon change with the character of the discharge and they observed unaccountable variations in the spectra of these elements, such as the appearance, on a single occasion, of unknown lines in the xenon spectrum which may indicate the presence of another body, but of this, again, they are as yet unwilling to speak with certainty.

Relations to the Periodic System.

There remains only the discussion of the relation of the members of this group to the periodic system.

A very considerable number of papers bearing upon this question are to be found in the journals; but, as many of these were written before the discovery of helium, and most of them before the knowledge of the existence of neon, krypton, and xenon, the speculations of many of the authors need not be reproduced here. It is worthy of mention, however, that the existence of elements with atomic weights approximating those of the members of the argon group, and probably without chemical activity, had been predicted by Flawitzsky, Julius Thomsen, and Boisbaudran. Flawitzsky and Thomsen arrived independently at the same conclusions, about 1887. They noticed that while the electro-chemical character of the members of a specific series change gradually, the change from the negative element of one series to the electro-positive element at the beginning of the next is most abrupt, and within a few units difference in atomic weights. If the properties of the elements are periodic functions of the atomic weights, then mathematical considerations would lead to the conclusion that such a change from negative to positive must theoretically involve an intermediate stage corresponding to zero or infinity — the latter case according with a sudden change, such as that noted. Thomsen calculates values for atomic weights of elements the electrochemical character of which should be $\pm\infty$ (that is, of no valence) as 4, 20, 36, 84, 132, 272, 292, — values which in part accord fairly with the atomic weights of the argon group, although he was disposed to assign to argon an atomic weight 20.

On the basis of a study of the forms of the atoms, Sedgwick arrived, in 1890, at the conclusion that there should be an inactive element possessing an atomic weight about that of argon, the atom of which should be spherical in form; and, since according to his

notions, the valence of an element was the consequence of the existence of flattened surfaces on the otherwise spherical surfaces of its atoms, such elements should show no tendency to unite with others. Subsequently he also predicted an inactive element of the atomic weight of neon.

Boisbaudran, shortly before the discovery of argon, arranged a classification of the elements with reference to their atomic weights, from the study of which he predicted the existence of elements with atomic weights 20, 36.5, 84, and 132, of non-metallic character and even atomicity. He was inclined to regard argon as the first representative of this series. No comment has apparently been made by Boisbaudran regarding the other members of the argon group.

Perhaps the first question to be asked is: Does our present knowledge of these recently discovered substances justify us in attempting to assign them places in Mendelejeff's system? Have they been shown to be elements in the sense in which the other members of the system are so regarded? These questions have been variously answered.

Rayleigh, Ramsay, and Travers are plainly inclined to regard these bodies as elementary in their character. That is, they do *not* regard them as made up of any combinations of atoms of known or unknown elements, and they *do* regard the gases which they finally weighed, and to which they assigned atomic weights, as essentially pure and free from other as yet unidentified substances, and they further regard the members of the argon group as entitled to a place in the periodic system, to be determined as far as possible by the *physical* properties which they exhibit.

On the other hand, Piccini[1] maintains that Mendelejeff's classification is based essentially on chemical principles; that the physical properties of the elements are subordinate with respect to this classification, and that in the absence of any chemical data, these bodies cannot be regarded as "elements," which Mendelejeff defines as "those material constituents of simple or compound bodies which occasion their physical and chemical behavior." Piccini appears, however, to be a rather ardent advocate of the infallibility of the Mendelejeff classification as it stands, and seems to fear that an attempt to force these new members into some place in the system will tend to discredit the whole principle. It is probable that his contention that argon and

[1] *Zeitschr. anorg. chem.*, 19, 295.

its associates have no proper place in the periodic system will hardly find general acceptance.

To return for a moment to the question whether these members of the argon group are to be regarded as elements, a very recent paper by Martin[1] should be mentioned, in which he contends that their elementary character is not proven beyond question, and cannot be, in the absence of chemical reactions. He remarks that argon might, for example, be a mixture of gases varying but little (one or two units) from each other in atomic weights, — as do iron, cobalt, and nickel. To this no positive reply can be made; yet, in the case of argon, it would appear that in such a long series of fractionation experiments some differences in density or spectrum would point to the presence of a mixture of gases, if such existed. The experiments of Olzewski with the liquid gas, which indicate a definite and constant boiling and freezing point, confirm this position.

Assuming then, for the moment, the elementary character of helium, argon, etc., what atomic weight shall be assigned to them? The densities as compared with hydrogen (1.008), as given in the table (page 227), are experimental data, free from all hypothesis, and the molecular weights are twice these values.

But what shall we say as to the number of atoms in the molecules? Shall we accept the deductions from the ratios of the values for the specific heat at constant pressure and constant volume, and say that the molecules are all monatomic? Again there are dissenting voices.

It is pointed out that that argument depends upon an assumed actual collision of the molecules, whereby a part of the energy of translatory motion is converted into rotational motion of the parts of the molecule, and that if, because of a repulsive force between the molecules, such actual contact does not occur, the basis for the deduction may not, at least in the case of molecules with compact structure, be sound. It is further noted that there may be molecules whose atoms are so closely united that the molecule is practically spherical in form, and in which rotational energy cannot, therefore, be detected; again, that the ratio of the specific heats in the case of avowedly diatomic substances varies considerably, and seems in some cases to grow less as the chemical activity increases, as in the case of chlorine, which if the reverse were true, might explain the high value for these elements, (this is not, however, borne out in the case of oxygen and nitrogen); once

[1] *Proc. Chem. Soc.* (Lond.), 17, 259.

more it is noted that a monatomic element resembles in some degree a nascent element, and this seems incompatible with chemical inertness; and finally, that argon, if considered alone, would fit rather better in the system with an atomic weight 20 than one of 40. Most of these arguments appear to antedate the discovery of the newer members of the argon group, and taken in connection with the behavior of mercury, they do not appear sufficiently convincing to overthrow the previous assumption of monatomicity, which finds support in the fact that argon and helium, at least, diffuse more rapidly than the polyatomic gases, and in the very low boiling-point of argon, and especially of helium, which, if its molecule were diatomic, should be higher than that of hydrogen.

Without attempting to settle the question finally, let us assume momentarily the validity of the proof of the monatomic character of the atoms of all of these elements, and see to what it leads. A brief examination of the periodic system suffices to show that argon with an atomic weight of 40 cannot be made to fit smoothly into the scheme. With this exception, the elements will find a place in the eighth group if we assign to them the values for their atomic weights determined by Ramsay. He inserts them between the halogen group and the sodium group, as shown by the table below. It is to be noted here that hydrogen becomes the first member of the halogen group — a position for it which has been defended by Professor Masson.[1]

H	He	Li	Be
1	4	7	9
F	Ne	Na	Mg
19	20	23	24
Cl	A	K	Ca
35.5	40	39	40
Br	Kr	Rb	Sr
80	82	85	87
I	X	Cs	Ba
127	128	133	137

[1] *Chem. News*, 73, 280.

This does not, however, account for the anomally in the value for argon, which should place that element on the other side of potassium, but Ramsay remarks that the difficulty here is no greater than with tellurium, or cobalt, both members of the eighth group at present.

It may be remarked here that Ramsay regards it as improbable that an element of the argon group heavier than xenon will be found, arguing in part from the analogies between xenon and iodine, and caesium and barium. His experiments indicate that such an element can only exist in the atmosphere in extremely minute quantities, if at all.

To show how far some of the observed properties of these elements agree with the requirements of the periodic law, the curve (Fig. 1) representing the refraction equivalents of the various elements, and the curve

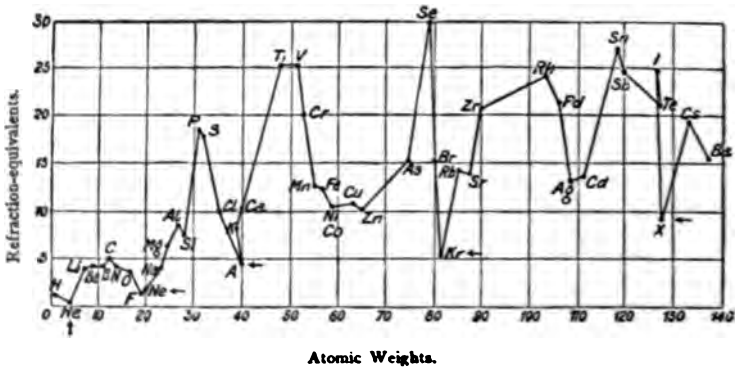


FIG. 1.—RELATION BETWEEN REFRACTION-EQUIVALENTS AND ATOMIC WEIGHTS. (From Ramsay and Travers.)

(Fig. 2) showing their atomic volumes, are reproduced here. It will be noted that, in the one case, the elements of the argon group are all at minimum points of the curve; in the other, they occupy corresponding positions on the ascending portions of the curve, except that the position of argon is abnormal in each case. A curve showing the melting-points exhibits the same approximation to the law as in these two instances. The similarity in position of argon and tellurium should be noted.

It is evident that the value for the density of krypton, as determined by Ladenburg and Krugel (from which the atomic weight would be about 50) would throw this element entirely out of line with the others. Of the merit of the work of these investigators, as compared with that of Ramsay and Travers, it seems impossible to express a

well-founded opinion, and one can hardly do more than merely to present the result of their work, without attempting to draw conclusions from it.

James Lewis Howe[1] has given some reasons for the assignment of the helium-xenon family to the eighth group, which deserve some mention. He points out, as already noted, that the position assigned to argon, if we assume its atomic weight to be 40, is no more anomalous than that of cobalt and tellurium. He suggests that it is not impossible that atomic weight of an element need not in every case have a value which is intermediate between those of the elements between which it

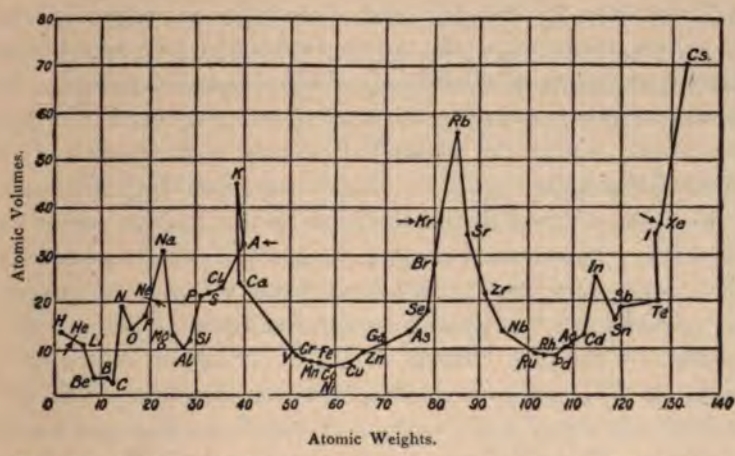


FIG. 2. — RELATION BETWEEN ATOMIC VOLUMES AND ATOMIC WEIGHTS. (From Ramsay and Travers.)

lies with respect to its properties; that is, he conceives it to be possible that an element may occasionally have an atomic weight slightly greater than the element which follows it, without necessarily overthrowing the system. He suggests that the atomic weight may be made up of two factors; for example: $a\,n$ and $\beta\,m$. $a\,n$ is relatively large and simple, and $\beta\,m$ small and complex. In most cases, the atomic weight increases as $a\,n$ increases, but with certain elements the quantity $\beta\,m$ may have sufficient influence to cause the atomic weight to temporarily retrograde. He points out that if we neglect the abnormal value in the case of argon, and place the members of this group of inactive elements in group eight of the periodic system, arranged according to the suggestion of Venable, that these elements

[1] *Chem. News*, 80, 74.

form a transition group from the halogens to the alkalis, except that there is no halogen of lower weight than fluorine. He points out that the valence toward hydrogen is one in the seventh group, and would naturally be zero in the eighth; that the valence toward chlorine and other similar elements in the first group is one, and would therefore be preceded by a valence of zero; that the valence toward oxygen is affected by the electro-chemical character of the elements, so that, since fluorine forms no oxide, we should expect no oxygen compounds of this member of the eighth group.

Venable gives to the members of the first period the name of "group" elements; to those of the second period, "type" elements, since it is they, rather than the group elements, which foreshadow the character of the succeeding elements of the respective groups. In this classification argon would appear as a type element, and the question at once arises: Can it be associated in this respect with any other elements of the eighth group? If we examine Venable's table, we find that, while in group I, the elements of the positive series closely resemble the type element argon, in group II, the positive series resemble magnesium less closely, and when we pass to group VII, the only element of the positive series, manganese, bears very little resemblance to the type element fluorine. It is not surprising then, that in group VIII this resemblance entirely disappears, and we find no similarity between iron, cobalt, and nickel on the one hand, and argon on the other. A similar examination of the table, with respect to the negative series, would lead to the same conclusion which Howe advances as a reason for assigning these new elements to that part of the system.

He considers the fact that helium, neon, and argon form a triad as strong evidence in favor of the elementary character of these type elements.

It is also true that the more recent work on the elements of the argon group with higher atomic weights, viz: krypton and xenon, have assigned to them atomic weights which will place them in the same relations to bromine and iodine that argon has to chlorine, if we place that element in the eighth group, neglecting, however, the value 59 for krypton as already noted.

Finally, it should be noted that Crookes has arranged the elements upon a series of figure-eight curves, which combine the spiral and zig-zag, and he arrives at the same conclusions as those just stated,

that the argon family finds a place in the eighth group, as transitional between the seventh and first groups. He regards this absence of chemical properties as the result of the pause in the swing of the pendulum between the electro-negative and the electro-positive elements. He, too, would place hydrogen as the first member of the halogen series.

The views of Howe and Crookes are representative with respect to the position to be assigned to the members of the argon family in the Mendelejeff system. Exception is taken only by those who hold that these substances are types of a new class of bodies for which we have no precedents or place, and who would, therefore, exclude them, at least temporarily, from the system altogether, to await future discoveries. No explanation, other than that of Howe, is offered for the anomaly in the case of argon; nor can we explain the apparent exceptions in the cases of tellurium and cobalt. Until we gain new light as to the meaning of the approximate periodicity of properties observed in most of the elements, or until our observations of these properties or our determinations of atomic weights have been proven faulty, perhaps we can do no better than to assign these elements (assuming them to be such) to the somewhat motley collection in the eighth group.

Such, then, is the outline of the recorded history of the members of this unique group, in which, as their discovery is a product of the work of our own time, we may properly take a deep interest. If I tell you that there are already over 250 articles in the journals upon these gases, it will be plain to you that what has been said represents but a portion of the material to be drawn upon. I can only hope that it includes the larger and the more important portion.

The following papers contain reviews of the published work to the dates named: (1895) Rayleigh and Ramsay: *Chem. News*, 71, 51; (1896) Ramsay: "The Gases of the Atmosphere," Macmillan; (1897) Parker: *J. Am. Chem. Soc.*, 19, 134; Mugdan: "Argon und Helium" in the "Sammlung chem.-techn. Vorträge"; (1898) Ramsay: *Ann. chim. phys.*, [7] 13, 433; Ramsay: *Ber.*, 31, 3111; (1900) Ramsay and Travers: *Ztschr. phys. Chem.*, 38, 641; (1901) Travers: "The Experimental Study of Gases," Macmillan.

The principal physical properties of the members of the argon group are stated in the appended table:

PHYSICAL PROPERTIES.

	Helium.	Neon.	Argon.	Krypton.	Xenon.	[Hydrogen.]
Density. H = 1.008	1.98	9.96	19.96	40.78 (29.40)	64.	
Atomic Weights.	3.96	19.92	39.92	81.56 (58.80)	128.	
Refractivity. Air = 1.	0.124	0.235	0.968	1.450	2.368	
Melting-point.	?	?	−187.9°	−169°	−140°	−257°
Boiling-point at 760 mm.	(−268 ?)	about (−243—233°)	−186.1°	−151.67°	−109.1°	−252°
Critical Temperature.	?	below (−210°)	−117.4°	−62.5°	−14.75	−240°
Critical Pressure.	?	?	40,200 mm.	41,240 mm.	43,500 mm.	11,600 mm.
Density of Liquid.	0.3 ?	1.0 ?	1.212	2.155	3.52	
Atomic Volume.	?	?	32.9	37.8	36.4	

One liter liquid air yields $\frac{1}{10}$ — $\frac{8}{10}$ c.c. xenon.
Lowest temperature obtained with liquid hydrogen is about −260°.

AN APPARATUS FOR COLLECTING SAMPLES OF WATER AT VARIOUS DEPTHS.

By EARLE B. PHELPS, S.B.

Received December 23, 1901.

For many years chemists engaged in the sanitary analysis of water have recognized the value of the oxygen dissolved determination as a rough indication of the condition of a ground water. Drown[1] has given us some valuable information regarding the relation of the dissolved oxygen in ponds and reservoirs to the depth. Whipple and Parker[2] have shown the effect of the oxygen and the carbon dioxide in a water upon the organisms which it contains.

The methods usually employed for securing samples of water for a chemical analysis cannot be used for an oxygen dissolved sample owing to the rapid absorption of the atmospheric oxygen by the water. The method generally employed for taking a sample for oxygen dissolved consists in dropping a rubber hose into the water and, by means of a suction pump, forcing a stream of water into the bottom of the sample bottle. This process is continued until water amounting in volume to several times the capacity of the bottle has passed through it, thus washing out all water which has come into contact with the air. A second method, often used, consists in fitting a sampling bottle with two tubes. One, the inlet tube, extends to the bottom of the bottle and is carried through the stopper and about an inch above it. The other tube has its lower end just within the stopper and is connected with the open air by a rubber tube. Since there is no overflow possible, the sample has been in contact with the air in the bottle for a short time.

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[1] **On the amount of Dissolved Oxygen contained in Waters of Ponds and Reservoirs at Different Depths,** Report of the Massachusetts State Board of Health, 1891 and 1892.

[2] **Whipple and Parker:** Dissolved Oxygen and Carbonic Acid in Water and their effect on the **Micro-organisms,** Trans. of the Amer. Mic. Soc., Vol. XXII.

Being under the necessity of taking a large number of samples for the determination of dissolved oxygen, in a recent study of the Springfield Water Supply by the State Board of Health, the writer has devised an apparatus for this purpose which, he believes, combines the accuracy of the cumbersome pump and hose method with the simplicity of the second, or bottle, method described above. The device is so simple that it has, no doubt, been previously used; but so far as the writer is aware, it has never before been described.

The arrangement of the sampling bottles is shown in the accom-

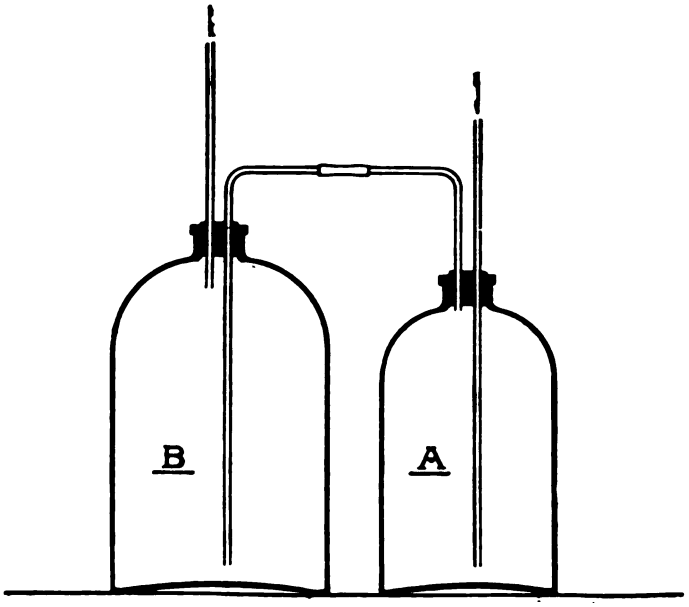


FIG. 1.—APPARATUS FOR COLLECTING SAMPLES OF WATER AT VARIOUS DEPTHS.

panying diagram. *A* and *B* are two bottles of about 250 and 500 c.c. capacity respectively, and are fitted with glass and rubber connections as indicated. They are enclosed in a suitable weighted wire cage to which is attached a suspending cord with graduations indicating the depth.

The method of operating is as follows: The cage containing the bottles is dropped quickly to the desired depth. The tube of the bottle *B* being higher than that of the bottle *A*, water will flow in through *A* and air pass out through *B*. *A* will be filled with water which will then overflow into *B*. When *B* is also full, which condition is shown

by the cessation of air bubbles rising to the surface, *A* has been filled three times. The water which entered during the descent has all been washed over into *B*, and the water which *A* now contains has not been in contact with the air. Thus one obtains a fair sample of the water at the particular depth at which the determination is to be made. The cage is hauled to the surface, the rubber stopper removed, and a glass stopper quickly inserted. The reagents are then added as usual.

The temperature may be determined with sufficient accuracy in the bottle *B* after bringing it to the surface. A very convenient method for a more careful study of the temperature is to use in connection with this apparatus a Whipple Thermaphone.

Although devised primarily for the collection of samples for the oxygen dissolved determination, this apparatus may be used for a variety of purposes. The writer has frequently used the water in the bottle *B* for the determinations of the micro-organisms.

It may appear that the bottle *B* is larger than an accurate determination requires. An experiment to determine this point was made as follows: A few drops of a strong solution of Fuchsine were added to the bottle *A* and a stream of water allowed to flow through the apparatus. By this means the actual course of the water through the apparatus could be readily followed. It was found that many eddy currents were formed and that *A* had to be filled at least three times before the dye was completely expelled.

The following table contains the results of two series of determinations made with this apparatus in a shallow pond:

I. August 21. High Wind.		II. September 13. Light Breeze.	
Depth.	Oxygen Dissolved. Per cent. of Saturation.	Depth.	Oxygen Dissolved. Per cent. of Saturation.
5 feet	100.0	0 feet.	76.5
10 "	61.9	3 "	63.1
14 " (bottom)	32.4	6 "	53.4
		9 "	52.0
		12 "	44.2
		14 " (bottom)	41.1

Laboratory of the Springfield Water Commissioners.
Ludlow, Massachusetts, December 22, 1901.

BOOK REVIEW.

Cyanide Practice. By Alfred James. London, Spon. New York, Engineering and Mining Journal. 1902, p. 174. ill. Price, $5.00.

This book appears to be a semi-official statement of the history and development of the cyanide process under the Scotch parent company which is the owner of the Mac Arthur-Forrest patents. The author, who early became connected with this company and was in charge of the South African field, where the process first became a commercial success, records in this book mainly the results of his own practical experience. The book is therefore not a text-book, which necessarily must be to a large extent a compilation by competent authority, but a record of some of the investigations carried on by the company, which have made the process what it is today, and of the practical results attained in actual work. The results represent mainly the work in South Africa, Australia, and New Zealand. American practice is referred to only here and there. The whole manner of treatment indicates that the author presupposes the reader to be familiar with cyaniding in general, and to be prepared to appreciate the detailed practical information given; sometimes, however, he goes to the other extreme and gives elementary A B C which seems superfluous. The arrangement of the matter in the book cannot be called entirely satisfactory.

The first chapter, "Investigation of Samples," is very concise and fairly complete. It is taken from the author's paper read before the Institute of Mining and Metallurgy (1894–95. 3, 369), as is much of that which follows under the next two headings, "Plant" and "Extraction." The chapter on the plant gives many useful details; extraction covers crushing, leaching, chemical reactions, clean-up, fusion, administration, labor, capacity of labor and "Pointers," intended for all men connected with the works, from director to the foreman and the melter.

It sounds rather odd to have the author say (p. 56), in his discus-

sion of the precipitation of gold by means of zinc, that, with the possible exception of electricity, no other precipitant than zinc shavings had made any headway, when we consider the steadily increasing use of zinc fume (blue powder) in American cyanide plants.

The chapter on the "Treatment of Slimes" is very instructive. It shows why decantation has become the standard method of treatment where there is sufficient water to permit of its being applied. It is not quite clear why the author has given so much space to the Pelatan-Clerici process; he gives only American practice, and here the process can hardly be said to have achieved sufficient success to warrant such extended discussion. The Sulman bromocyanide process is discussed in full. In this country a good many experiments have been carried on with it, but it has failed to be adopted.

The chapters on "Dry Crushing" and on "Costs" are unsatisfactory, at least from the American point of view. The "Notes on Extraction Work" is in part a reprint of the author's paper read before the American Institute of Mining Engineers (1897. 17, 278). On page 124 is another reference to the use of zinc dust, which is incorrect so far at least as one large American plant is concerned, the bullion of which is not so impure as when zinc shavings were used, and which requires less zinc dust for precipitation than it did shavings.

Under "Losses in Cleaning-up" there are found many interesting figures. It seems surprising to find the chemistry of the process discussed here (on page 147, the whole book having 172 pages). The chapter contains some new suggestions on determinations. Under "Recent Cyanide Practice" are given some more useful details. It is interesting to note, on page 160, that in South Africa there are found similar difficulties in precipitating gold from dilute cyanide solutions as in the United States.

To sum up,— The book will not delight the theoretical man nor the general reader; it will do excellent service to the engineer in charge of works, as he will find, what he usually looks for in vain, the record of experience of a man who has had to do much with the details of the work. Every cyanide company ought to have one or more office copies at the works, in order to afford employees every possible facility for becoming familiar with the contents of the book.

H. O. HOFMAN.

March 25, 1902.

TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. XV SEPTEMBER, 1902 No. 3

PROCEEDINGS OF THE SOCIETY OF ARTS.

FORTIETH YEAR, 1901–1902.

BOSTON, March 27, 1902.

THE 565th regular meeting of the SOCIETY OF ARTS was held in the Rogers Building on this day at 8 P.M., Professor Talbot presiding. One hundred and twenty-two persons were present.

Mr. William D. Grier, Secretary of the Boston Scientific Society, was elected to membership. The paper of the evening was by Mr. Walter E. Piper, Assistant Superintendent of the Boston Rubber Shoe Company, on "India Rubber: A Description of the Crude Gum and its Manufacture." The lecture was illustrated with slides, showing the various species of rubber trees, the method of collecting the gum, and various stages in the manufacture of rubber shoes. An unusually complete collection of crude gums was shown.

BOSTON, April 10, 1902.

The 566th regular meeting of the SOCIETY OF ARTS was held in the Walker Building, Room 22, on this day at the usual hour, Pro-

fessor Sedgwick presiding. One hundred and fifty persons were present.

Professor John O. Sumner of the Institute was elected to Associate Membership.

Professor C. H. Benjamin, Supervising Engineer, City of Cleveland, gave a most interesting lecture on "Smoke and its Abatement in Large Cities." The lecture was illustrated by slides showing the smoking of chimneys in Cleveland before and after the introduction of automatic stokers and other smoke-consuming devices. Professor Benjamin's paper will appear in the TECHNOLOGY QUARTERLY.

At the conclusion of the paper of the evening, Mr. Russell Raynor, Inspector of Smoke in New York City, told of the methods used there by the Board of Health to abate the smoke nuisance, and enforce the smoke regulations.

Through the courtesy of Mr. W. Lyman Underwood, a number of slides were shown of chimneys in Boston which are notoriously bad smokers.

A vote of thanks was most heartily extended to Professor Benjamin, Mr. Raynor, and Mr. Underwood.

BOSTON, April 24, 1902.

The 567th regular meeting of the SOCIETY OF ARTS was held on this day at the usual hour, in Room 22, Walker Building, President Pritchett in the chair. Two hundred persons were present.

Mr. Edwin E. Norton and Mr. George P. Shute were elected to Associate Membership. In accordance with the By-Laws, the following Committee were appointed by the President to nominate the Executive Committee for the ensuing year: Professors Swain, Lanza, and Talbot, Mr. Bemis, and Dr. Walker.

At the conclusion of the business, the Honorable E. J. Hill, Member of the United States House of Representatives, was introduced and gave an admirable lecture on "A Trip through Siberia." The lecture was followed with the greatest interest by those present, and their appreciation was shown in the hearty vote of thanks extended to the speaker.

BOSTON, May 8, 1902.

The 40th Annual Meeting (the 568th regular meeting) of the SOCIETY OF ARTS was held at the Institute, Walker Building, on this day at 8 P.M., Dr. Pritchett in the chair.

Two hundred and twenty-five persons were present. The Annual Report of the Executive Committee was read and accepted.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE PRESENTED AT THE FORTIETH ANNUAL MEETING OF THE SOCIETY OF ARTS, MAY 8TH, 1902.

The first meeting of the SOCIETY OF ARTS for the present year was held on October 10, 1901. Fourteen meetings have been held, with an average attendance of two hundred and sixteen.

During the last three years there has been a steady gain in the attendance, which has reached this year three times that of any corresponding period since 1875. Another feature, most gratifying to the Executive Committee, is the increased interest manifested by the students of the Institute in these meetings.

The following papers have been read: —

"The Olympia: A General Description of this Famous Ship, and a Discussion of the Development of Cruisers during the Past and the Tendency to Future Progress." Naval Constructor William J. Baxter, U. S. N.

"Present Condition of American Railroads as Compared with the Period of Depression, 1893–1898." Professor William Z. Ripley, Expert Agent on Transportation, U. S. Industrial Commission.

"The Importance of Catalytic Agents in Chemical Processes." Professor Arthur A. Noyes.

"The Development of the Nernst Lamp in America." Mr. Alex. J. Wurts, Manager Nernst Lamp Company.

"The Development of Locomotive Boilers, with Particular Reference to the Vanderbilt Boilers." Mr. Cornelius Vanderbilt.

"The New Star in Perseus." Professor George E. Hale, Director Yerkes Observatory.

"Utilization of Electricity in Mines." Mr. Calvin W. Rice, Electrician, New York Edison Company.

"Some Features of the Isthmian Canal Question." Professor W. H. Burr, Member U. S. Commission on the Isthmian Canal.

"Engineering in China." Mr. William Barclay Parson, Chief Engineer, New York Subway.

"Aluminum as a Reducing and a Heat-Producing Agent." Professor Heinrich O. Hofman.

"India Rubber: A Description of the Crude Gum and its Manufacture." Mr. Walter E. Piper, Assistant Superintendent, Boston Rubber Shoe Company.

"Smoke and its Abatement in Large Cities." Professor C. H. Benjamin, Supervising Engineer, City of Cleveland, Ohio.

"A Trip through Siberia." Hon. E. J. Hill, Member of the United States House of Representatives.

"Success in Long-Distance Power Transmission." Dr. F. A. C. Perrine, President of the Stanley Electric Manufacturing Company.

At the beginning of the year, the Associate Membership was three hundred and fifty-four. Of these members one has died, five resigned, one cancelled; twenty-two elected, making the present membership three hundred and sixty-nine. There are thirty-eight Life Members.

The Publication of the TECHNOLOGY QUARTERLY has been continued, as before, under the auspices of the SOCIETY OF ARTS. There has been a regrettable difficulty in obtaining manuscripts of papers read before the Society. Nevertheless, the QUARTERLY has not lacked material, and has published contributions from a considerable number of the departments of the school. One of the most notable of these contributions is the "Report of the Massachusetts Institute of Technology Eclipse Expedition to Sumatra in 1901," by Professor Burton and Messrs. H. M. Smith, G. L. Hosmer, and G. H. Matthes. Another important contribution from the Civil Engineering Department is "Tests of the Massachusetts Institute of Technology Tape Apparatus," by Professor Burton and Mr. John F. Hayford of the United States Coast and Geodetic Survey. The Mechanical Engineering Department contributed the usual quota of "Results of Tests" during the summer, and also a paper by Mr. J. C. Riley, on "The Pulsometer Steam Pump." From the Physical Department we have a paper by Professor Laws, on "An Apparatus for Recording Alternating Current Waves," and one by him and Dr. Cooledge on "An Apparatus for the Rapid Comparison of Voltmeters." The Chemical Department has furnished three "Contributions from the Laboratory of Sanitary Chemistry" by Mrs. Richards, Mr. Woodman, and Miss Hyams, a paper by Professor Gill and Mr. Healey on "Some Thermal Properties of Naphthas and Kerosenes," and the "Review of American Chemical Research," edited by Professor Noyes, to December. It was found impracticable for the Chemical Department to continue the preparation of the *Review* and its publication was discontinued with the issue of the December number of the QUARTERLY. Mr. Winslow has contributed from the Biological Department a report on "Typhoid Fever at Newport, R. I., in 1900, and its Relation to Defective Sanitation," and we have had from Mr. Prescott a paper, "On the Application of Bacteriology to Certain Arts and Industries." The contributions from the Geological Department are two papers by Professor Crosby, one on "Tripolite Deposits of FitzGerald Lake," and the other on the "Geological History of the Hematite Iron Ores of the Antwerp and Fowler Belt in New York," and Mr. F. G. Clapp's thesis on the "Geological History of the Charles River." Messrs. Whipple and Jackson have continued their important series of papers on methods of water examination, and Mr. William Lincoln Smith has furnished a second part of his valuable "Study of Certain Shades and Globes for Electric Lights as used in Interior Illumination."

GEORGE W. BLODGETT,
DESMOND FITZGERALD,
EDMUND H. HEWINS,
CHARLES T. MAIN,
JAMES P. MUNROE.
} *Executive Committee.*

The Secretary read a communication from the Committee on Nominations, in which the following gentlemen were named as candidates for the Executive Committee for the year 1902–1903: George W. Blodgett, Desmond FitzGerald, Edmund H. Hewins, Charles T. Main and James P. Monroe. Mr. George V. Wendell was nominated for Secretary. A ballot was taken, which resulted in the election of the above named candidates.

Professor James F. Norris was elected to Associate Membership.

The following papers were presented by title:

"A Study of Self-Purification in the Sudbury River," by A. G. Woodman, C. E.-A. Winslow, and P. Hansen.

"On the Use of Gelatin in Culture Media," by G. C. Whipple.

"Origin and Relations of the Auriferous Veins of Algoma (Western Ontario)," by W. O. Crosby.

"History of Elements of the Argon Group," by H. P. Talbot.

Dr. F. A. C. Perrine, President of the Stanley Electric Manufacturing Company, gave a most valuable and interesting lecture on "Success in Long-Distance Power Transmission." The paper will appear in full in June number of the QUARTERLY. The thanks of the Society were extended to Dr. Perrine.

GEORGE V. WENDELL, *Secretary.*

THE EFFICIENCY OF PHOTOGRAPHIC SHUTTERS.

By LOUIS DERR.

Received June 26, 1902.

CAMERA exposures longer than one-fifth of a second can be made by uncapping the lens, but below this limit some form of automatic shutter is necessary. In photographing objects in motion the allowable displacement of the image (generally 0.01 inch) usually limits the exposure to a very small fraction of a second; and in such cases it is often a matter of considerable difficulty to get enough light upon the plate, even under favorable conditions.

A part of the difficulty is in the loss of light due to the action of the shutter itself. In all rapid shutters working at the lens, a large portion of the time of exposure is consumed in opening to full aperture and then in closing, the time during which the shutter is fully open being a rather small fraction of the whole. During the opening and closing periods the lens is only partly uncovered, and therefore works at a virtually smaller aperture, with corresponding loss of light. The so-called "focal plane" shutters are free from this objection, but have the disadvantages of an undesirable bulk and certain intricacies of manipulation. These shutters operate directly in front of the plate. The moving part is a curtain like a miniature window-shade, having an adjustable slit across the whole width of the plate, and worked by a controllable spring.

Shutters working at the lens may be divided into two classes. In one class the shutter blades open and close just before or behind the diaphragm, but are entirely independent of it. In the other class, the so-called "diaphragm" shutters, the blades themselves form the diaphragm, opening only to the desired size of aperture, as determined by a suitable index.

The efficiency of a shutter of any type may be defined as the ratio L/L', where L is the amount of light actually admitted during exposure, and L' the quantity which would have been admitted if the

shutter had opened instantly to its full aperture, remained wide open during the entire exposure, and then closed instantly. Since this condition cannot be realized by a shutter working at the lens, it follows that the efficiency of all such apparatus is less than unity. The discussion of the value of this fraction, often disappointingly small, is the object of this paper.

As a rule, the analytical determination of the efficiency is not difficult for plain forms of shutter aperture when the law of motion is a simple one. A few cases follow:

CASE I. Let a rectangular shutter *ab* (Figure 1) move past an opening of the same length. Let x represent the distance moved in t seconds, counting from the instant of opening. Then the area

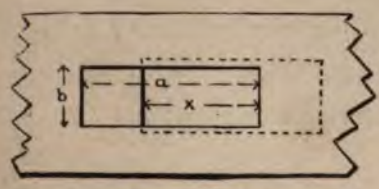


FIG. 1.—RECTANGULAR SHUTTER.

bx is the aperture at the instant t; and if the quantity of light that passes through unit area per second be denoted by I, the quantity that will pass through the aperture in the time dt will be

$$dL = b\,x\,I\,dt.$$

The total quantity of light admitted during the opening can be found from this if the relation between t and x is determined; that is, if the law of motion is known. Assuming in the present case that the motion is uniform, we have

$$x : a :: t : T,$$

where T is the time required to open fully, and substituting for x its value in terms of t,

$$L = \frac{abI}{T}\int_0^T t\,dt = \frac{1}{2}\,a\,b\,I\,T.$$

Since light is admitted during the whole time T, it follows that if

the shutter had been fully open from the beginning, the total quantity would have been

$$L' = ab\,I\,T.$$

A similar analysis holds for the act of closing. The efficiency of this form of shutter is therefore

$$\eta = 0.500.$$

CASE II. Let the length c of the shutter be greater than the length a of the opening past which it moves. Then the following quantities of light will be admitted :

During opening, $\frac{1}{2}\,a\,b\,I\,T.$

While fully open, $a\,b\,I\left(\frac{c-a}{a}\right)T.$

During closing, $\frac{1}{2}\,a\,b\,I\,T.$

Therefore $L = a\,b\,I\left(1+\frac{c-a}{a}\right)T,$

$$L' = a\,b\,I\left(2+\frac{c-a}{a}\right)T.$$

The efficiency is consequently

$$\eta = \frac{c}{c+a}$$

Thus for high efficiency c should be considerably greater than a. This is the principle of curtain shutters working at the lens.

CASE III. If the aperture is a circle moving past another circle of the same radius R (Figure 2), then while partially open the aperture is composed of two circular segments. Therefore

$$dL = 2\,R^2\,(\alpha - \sin\alpha\cos\alpha)\,I\,dt.$$

If the motion is uniform, we have

$$t : T :: (AB) : 2\,R$$
$$:: 2\,R \text{ versin } \alpha : 2\,R.$$

Substituting for t its value in terms of α and integrating between the limits $\pi/2$ and 0, we obtain for this form

$$\eta = 0.4244.$$

CASE IV. If this shutter can be arranged to open uniformly during T seconds, remain fully open during T seconds more, and then close uniformly during a third interval of T seconds, the efficiency rises to

$$\eta = 0.616, \text{ a noticeable gain.}$$

In various types of shutter substantially the same result is obtained by using blades of large aperture moving over a smaller opening, as indicated by the small circle in Figure 2. In this way full opening is

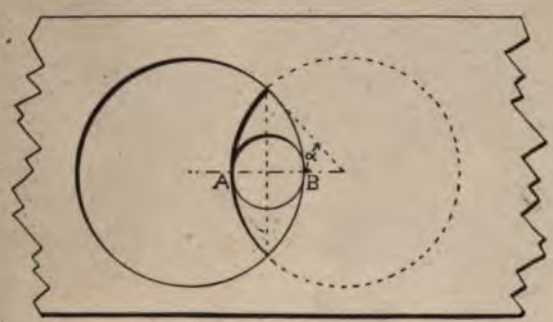


FIG. 2.—SHUTTER WITH CIRCULAR APERTURE.

realized during a considerable portion of the exposure. This is illustrated by the seventh photograph of Figure 3. In other words, the efficiency is higher for small stops. This at once suggests that for a given lens an increased shutter efficiency might be secured by using a shutter one or two sizes larger than necessary, and stopping it down with a diaphragm. The objection to this is the difficulty of getting a large shutter to work at the speed sometimes required.

CASE V. Diaphragm shutter. In this case let the radius of a circular aperture increase uniformly from zero to the maximum value R, and then decrease uniformly to zero again. Then at t seconds from the beginning the open area is πr^2, and the quantity of light admitted through it in the time dt is

$$dL = \pi r^2 \, I \, dt.$$

Also, $t : T :: r : R.$

FIG. 3. — THE APERTURES OF VARIOUS SHUTTERS PHOTOGRAPHED IN SUCCESSIVE STAGES OF OPENING AND CLOSING.

Substituting for r its value in terms of t, and integrating between the limits of T and 0, we have, for the total quantity of light admitted during opening,

$$L = \frac{1}{3} \pi R^2 I T.$$

The total quantity which would pass through an opening πR^2 in the time T is

$$L' = \pi R^2 I T.$$

A similar analysis holds for the closing; hence, for this form,

$$\eta = 0.333.$$

Cases VI and VII. If the mechanism is arranged to keep the shutter fully open during part of the exposure, the above low value may be greatly increased. If the shutter remains open for an additional time T, the efficiency becomes 0.444. If the time of full opening be extended to $2T$, the efficiency rises to 0.667. This is the principle of several recent patterns of diaphragm shutter, and is illustrated by the fifth photograph of Figure 3.

Cases VIII and IX. When the law of motion is less simple, the analysis becomes more intricate, though hardly less elementary. If the shutter of Case I moves with uniformly accelerated motion, starting from rest at the instant of opening, the efficiency will be found to be 0.391. The diaphragm shutter of Case V, with uniformly accelerated motion as above, has its efficiency lowered to 0.248.

This reduction of efficiency shows that the loss due to slow opening is not made up by the gain from rapid closing. It also indicates as a direct consequence that a shutter should be designed for rapid opening, and in such cases the closing will generally take care of itself. Most of the shutters examined by the writer require much less time for closing than for opening.

Numberless examples might be worked out, but their practical value is doubtful, since in the concrete case a knowledge of the circumstances of motion cannot well be assumed, and the variation in size of the shutter aperture during opening or closing certainly does not follow any simple law. The above analysis is therefore chiefly useful as an indication of the lines along which high efficiency is to be expected.

To examine the performance of a given shutter it is necessary to have a record of the various phases of its motion during the whole operation, and this requires a series of photographs of the shutter aperture at regular and very short intervals. To obtain these the writer has employed the apparatus shown in Figure 4. A mirror throws a beam of sunlight upon the shutter to be examined, the lens glass being removed. A large lens forms an image of the shutter aperture on a strip of photographic film wound on a small drum. This was rotated by a little electric motor at a rate equal to

FIG. 4.—THE PHOTOGRAPHIC APPARATUS.

about twenty feet a second. The apparatus was set up in a dark room, the sunbeam coming through a hole in the wall.

Snapping the shutter of course gives on the motionless film an image of the aperture, but if the drum is rotating rapidly, the image is drawn out into a long band whose width at any point is a measure of the shutter-aperture at the corresponding instant. The upper photograph of Figure 3 is such a record. It is similar to diagrams given by Abney.

In diaphragm shutters the aperture is always a regular polygon and a measurement of the width of the band at equal intervals gives all that is necessary to determine the area of the aperture at every

point of the exposure. These areas when plotted give a curve like that of the upper curve of Figure 5. Since the perfect shutter would be represented by a rectangle of the same base and height, the efficiency of the given shutter can be found by dividing the area of the curve (measured with a planimeter) by that of the enclosing rectangle.

When, however, the partly open shutter blades do not form a figure which can be determined from a single dimension, it becomes necessary to break up the continuous record into a series of separate images. This was done by the perforated disc shown in Figure 4. It has thirty-six holes near the rim, and is carried on the shaft of a second electric motor. It was placed so as to intercept the light from the lens except when a hole lay directly in the axis of the beam. The average speed

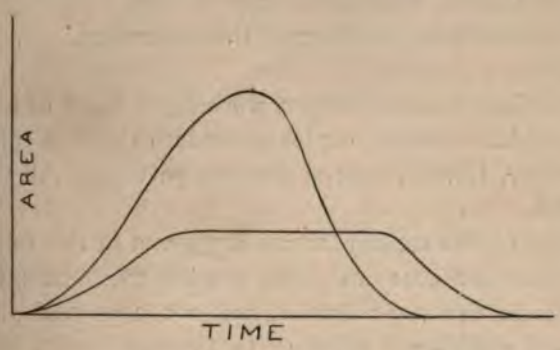


FIG. 5.—CURVES SHOWING THE CHANGES IN AREA OF APERTURE OF TWO SHUTTERS DURING EXPOSURE.

of the rotating disc was 515 holes per second, thus giving five or six images of the shutter for an exposure of 0.01 second, and correspondingly more for longer exposures.

The remaining photographs of Figure 3, except the seventh, are from records taken in this way of various shutters at full opening. The seventh is of a shutter at small opening. The rapid motion of the film blurs the images somewhat, though each represents an exposure of not over 0.0005 second. On the original films, however, the outlines are perfectly traceable and it was not found necessary to adopt more elaborate arrangements of the apparatus. The curious shapes of the apertures during the partial phases are well shown.

These images, from five to twenty in number for each film, were then measured by planimeter, and the areas plotted as before. The

lower curve of Figure 5 shows one such result, from a record like that of the seventh photograph of Figure 3.

In this way thirteen shutters were examined, and about one hundred films used. The shutters were as follows:

A. Two-blade shutter, working at the diaphragm.
B. Smaller size of A.
C. Four-blade shutter, working at the diaphragm.
D. Smaller size of C.
E. Two-blade pass-by shutter, working at the diaphragm.
F. Smaller size of D.
G. Diaphragm shutter.
H. Slightly smaller size of G.
I. Curtain shutter, working in front of lens.
J. Two-blade shutter, working at the diaphragm.
K Diaphragm shutter.
L. Single-blade pass-by shutter, working in front of lens.
M. Single-blade shutter, for insertion into the lens tube.

Of the above, L and M are of obsolete pattern. All the others are on the market.

The results of the measurements are given in the following table. For speeds between 0.01 and 0.04 second the efficiency varies irregularly, even in the same shutter, and not very markedly, so that it has been found sufficiently accurate to average results between these limits and to omit the speed altogether from the table. No attempt was made to measure the efficiencies at speeds below 0.06 second, as at slow speeds the efficiency is always very high and a knowledge of it not usually of importance. The figures 1, 2, 3, 4 at the heads of the columns in the table represent, as nearly as may be, full opening, one-half, one-quarter and one-eighth of the full area.

TABLE OF EFFICIENCIES

SHUTTER.	1	2	3	4
A	0.484	0.627	0.745	
B	0.494	0.583	0.731	0.755
C	0.491	0.609	0.693	0.772
D	0.645	0.697	0.735	0.846
E	0.546	0.702	0.820	
F	0.492	0.694	0.802	
G	0.457	0.555		
H	0.465			
I	0.724	0.746	0.782	
J	0.652	0.765		
K	0.400	0.406	0.511	
L	0.261			
M	0.603			

A very definite conclusion from the above table is that even the best shutters sacrifice a large part of the light-gathering power of the rapid lenses now so much used. It would therefore seem that effort should be directed to the improvement of the shutter rather than the lens.

The above method for measuring efficiency also gives the actual speed of the shutter with a fair degree of accuracy, provided that the speed of the perforated disc is known. In the experiments the speed was determined by using the disc as a siren and comparing it with standard tuning-forks. The result obtained in this way, however, is not a trustworthy measure of the shutter speed as affecting a photograph. Every aperture, no matter what its size, will be recorded on the film; but the light through the very small apertures at the beginning and end of the exposure, when the shutter is used in the regular way, will be quite without effect when spread out over a plate. In other words, the above method may be expected to give speeds that are too slow. In cases like No. 5 of Figure 3 there was a close agreement with the results of other methods. In shutters working as illustrated in No. 4 of Figure 3, the discrepancy was marked, as was expected.

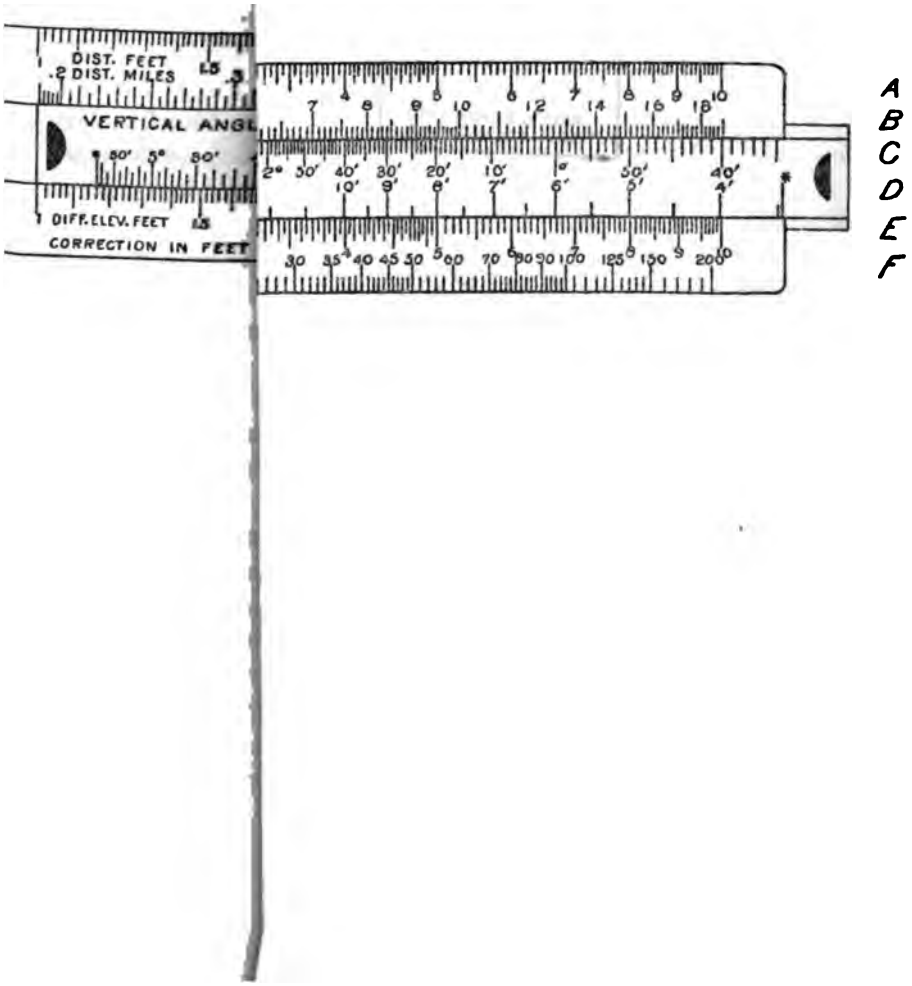
THE UNITED STATES GEOLOGICAL SURVEY TOPOGRAPHIC SLIDE RULE.

By GERARD H. MATTHES, S.B.

Read [illegible] May [illegible] 1902

In designing this instrument the writer has had in mind more particularly the needs of the topographic branch of the United States Geological Survey. In the performance of what may be called their routine work, the topographers and their assistants are called upon to make a large number of computations, many of which involve trigonometric functions, and for the facilitation of which various forms of tables have been in use. However excellent and convenient tables of this kind may be, they all possess the objectionable feature of being made of paper, making their manipulation out of doors a continual source of annoyance. The futility of trying to do rapid work while being compelled to look up data in a book the pages of which are being blown by the wind, and the effects of such agencies as damp weather, sweaty hands, and scorching sun on paper articles of any kind, are facts too well known to be dwelt upon.

For the last four years the writer has made use of a metal slide rule manufactured by Kern and Company, for reducing stadia observations in connection with large-scale plane table surveys in the west, and has found the instrument to be vastly superior for stadia reductions to tables and diagrams, not only as regards ease of manipulation, but particularly as regards speed in attaining the desired results. Unlike paper articles, this compact german silver instrument never becomes disagreeable to handle, and unlike celluloid-faced wooden slide rules, it is unaffected by changes of temperature or by the humidity of the air. The saving of time effected by the use of this instrument has enabled the writer to carry on plane table surveys under conditions that compelled him to reduce his field party to a minimum, one rodman only aiding him in the work of surveying. At such times he has made the reductions on the spot, dispensing with the services of a station as-


DIST. FEET
.2 DIST. MILES
VERTICAL ANGL
DIFF. ELEV. FEET
CORRECTION IN FEET
A
B
C
D
E
F

sistant without experiencing appreciable loss of time. He has found it possible to carry on work in windy weather, when the only articles that could be kept on the plane table were the alidade and the slide rule, the angles being taken down and the figuring done on the wrapping paper covering the unused portions of the map. Had tables or diagrams been used at such times, the services of a station assistant would have been required or much precious time would have been wasted.

To overcome the limitations of the Kern rule and make an instrument adaptable to plane table work on any scale and for any contour interval, has been the object of the writer in designing the slide rule here illustrated. Modeled after the pattern of the Kern rule, it is provided with a slide and a rider, the slide bearing graduations on both faces and being reversible, while the rider is also graduated. The rule is made of german silver, is $10\frac{1}{2}$ inches long, and weighs $11\frac{1}{2}$ ounces. It is handsomely finished and is a model of careful workmanship, reflecting great credit on the manufacturers, Messrs. Kern and Company, of Aarau, Switzerland. Being specifically intended for field use, it is constructed of metal, it being a well known fact that no rule made of wood and celluloid remains true for any length of time when constantly exposed to atmospheric agencies. While it is incontrovertible that graduations on celluloid are by far more easily read than those on metal, experience has proved that graduations on metal when made sharp and clear, as they are in this instrument, stand forth very plainly in broad daylight out of doors, and no case has come to the writer's notice where difficulty has been experienced in reading the graduations.

In order to demonstrate the uses for which this instrument has been designed, a brief outline is here given of the problems which occur in such plane table work as is done by the United States Geological Survey. These problems, which have been referred to above as constituting the routine work of the topographers, demand immediate solution in the field.

The operations may be classed under two heads: Vertical angle or intersection work, and stadia work. In the former, prominent features are located on the map by intersection from two or more known points, vertical angles being determined in each instance. The vertical difference of elevation between each point of observation and the new point is then computed by multiplying the horizontal distance (scaled

from the map directly) by the tangent of the angle, and applying corrections for the effects of curvature of the earth, refraction of the atmosphere, and the height of the telescope above the ground. Computations of this character are made for each observation, thus affording a reliable check upon the elevation of the new point.

It will be noticed at once that these computations are not simple. The distance scaled from the map is obtained in terms of miles. The difference of elevation required must be in feet. Effects of curvature and refraction are variable quantities. It is essential that the correct functions be used in computing these corrections, for no rule of thumb or approximate method can be relied upon to give accurate results. Obviously, rapidity in making the various reductions is a prime requisite in the economic conduct of field operations, and tables and diagrams of different kinds have therefore been in use by the United States Geological Survey, which materially shorten the arithmetical work involved, and which also have the great advantage of being simple in their application. This renders it possible for men of mediocre school education and unacquainted with trigonometric functions to become, with comparatively little training, valuable field assistants. This is a feature of much importance, particularly in surveys in the Western States, where the average topographer finds at the commencement of each season's work that he has to break in a raw lot of cowboys and such other men as he may be able to pick up, all of whom are entirely unacquainted with the work.

The other class of work referred to above, in which distances and elevations are determined by the stadia method, is too well known to require description here. In the general topographic work of the Survey its use is chiefly confined to stadia traversing and large-scale surveys of reservoir sites or mining districts. The reduction of stadia observations is also performed with the aid of tables. The formulæ involved are as follows:

Vertical difference of elevation $= 100\, R \frac{\sin 2A}{2}$

Correction to distance for inclination of line of sight $= 100\, R \cos^2 A$

where R is the rod reading in feet, and A the vertical angle read to a point on the rod at a height above the ground equal to the height of the instrument. These formulæ do not take into account the correc-

tions for focal length and the distance of the objective from the center of the instrument, but these are so small as to be negligible.

In intersection work distances occur from a fraction of a mile up to 15 miles or more; distances exceeding 10 miles are avoided, however, since an error of one minute in the vertical angle will affect the elevation 16 feet at a distance of 10 miles, and 23 feet at a distance of 15 miles, while the uncertainty of refraction for such distances becomes very great. The vertical angles are usually small, except in canyon or high mountain topography.

In stadia work distances are short, rarely exceeding 2,500 feet, while, on the other hand, the vertical angles are as a rule larger than in intersection work, though seldom exceeding 30 degrees.

The slide rule is capable of making all the operations described, and while it is not expected that it will entirely replace the tables now in use, it is believed that many topographers will prefer it as being more rapid and serviceable than any existing tables. In canyon and high mountain topography, however, where vertical angles of great amplitude are frequent, tables will be found more satisfactory.

Following is a description of the graduated scales of the rule:

Scale A contains the logarithms of common numbers from log 1 up to log 100, plotted from left to right to a scale of log 10 = 12.5 c.m., and is to be used as a scale of distances in *feet*.

Scale B contains the same graduations as Scale A, the difference being that the initial point is at a different place. The arrangement of the two scales with respect to each other is such that distances on Scale B in terms of *miles*, correspond with their equivalents in terms of *feet* on Scale A, thus providing a convenient means of conversion from one unit of length into the other. Scale B commences with a distance of 0.19 mile and ends with 19 miles.

Scales C and D, marked "Vertical Angles," are provided with graduations corresponding to the logarithmic tangents of angles, and are plotted from right to left, being negative quantities. Scale D commences on the right with 00° 03′ 30″ and ends with 05° 40′; Scale C duplicates these angles from 00° 35′ to 05° 40′, and carries the graduations up to 30° 00′. Asterisks have been placed opposite indices used for reading the differences of elevation on Scale E; their use will be explained further on. They are of importance in another connection, however, as they indicate the angles for which the differences of elevation are respectively 0.001, 0.01, and 0.1 times the horizontal

distance, taking them in order from right to left; and if imagined projected on Scale C they represent the angles for which the differences of elevation likewise are 0.01, 0.1, and 1 times the horizontal distance. In this manner they are a valuable aid in determining the location of the decimal point when reading difference of elevation.

Scale E is identical in all respects with Scale A, and is to be used for obtaining the vertical difference of elevation between the point occupied by the instrument and the point sought, as hereinafter explained.

Scale F. In the construction of this scale use was made of the formula $D_m = \sqrt{\frac{C - R + 4.5}{0.574}}$ in which D_m is the horizontal distance in miles, C and R the corrections in feet for curvature and refraction, respectively, while the quantity 4.5 is a constant positive correction for the height of the telescope above the ground, the assumption being that as a rule this height is in the vicinity of 4.5 feet. The second member of the equation is always positive. The graduations on Scale F are merely the logarithmic distances in miles corresponding to corrections in even feet, and are plotted on the same basis as the distances in miles on Scale B. Scale F, therefore, gives the correction for curvature, refraction, and height of instrument combined, for any distance (in miles) on Scale B, commencing with a correction of 6 feet for a distance of 1.62 miles, and ending with a correction of 200 feet for a distance of 18.45 miles. For any distance less than 1.5 miles, the correction may be taken as + 5 feet.

Scale G (on the rider) contains the logarithms of the squares of cosines of angles from 0° to 40°. Being negative, they are laid off from right to left. The first graduation to the left of the 0° mark represents an angle of 4°; the succeeding ones stand for 6°, 8°, 10°, etc., up to 20°, from which point on the graduations represent single degrees.

Scales H and I, marked "Stadia Angles," are on the reverse side of the slide and do not appear in the illustration. They are similar in character to Scales C and D described above, and contain the logarithms of $\frac{1}{2}$ sin $2A$, where A is the vertical angle in stadia observations. The statements made in regard to Scales C and D apply equally to Scales H and I, except that the graduations on Scale I extend from 00° 03′ 30″ to 05° 45′, and on Scale H from 00° 35′ to 40° 00′. The asterisks

are placed as before, and will also be found useful in determining the position of the decimal point in obtaining the difference of elevation.

The 0° mark of Scale G, the pointers of the rider, and the index on the lower portion of the rider are in line with one another. This line is at right angles to the axis of the rule, and serves to project readings from any one scale to any other.

Directions for Using the Slide Rule.

1. Given the distance to a point in *feet*, to convert the same into *miles*, or *vice versa*.

To convert feet into miles, set the 0° graduation of the rider opposite the distance in feet, 2,350 feet in the illustration, and read the answer 0.445 mile on Scale B, opposite the pointers. The same result could also have been obtained by using the left portion of the rule. In either operation the position of the decimal point is determined mentally.

2. Given the distance to a point in *miles*, required the correction for curvature and refraction, and for height of instrument.

Set the pointers of the rider opposite the distance in miles on Scale B, and read the desired correction on Scale F opposite the index on the lower limb of the rider. Thus in the illustration, for a distance of 4.45 miles the correction is found to be nearly 16 feet. The graduations on Scale F hold good only for distances in miles using Scale B without shifting the decimal point.

3. Given the distance to a point in *miles*, and the vertical angle, required the difference of elevation in *feet*, neglecting corrections for curvature, refraction, and height of instrument.

The pointers of the rider are brought opposite the given distance in miles on Scale B. The slide bearing the graduations marked "Vertical Angles" is then moved until the desired angle is brought opposite the pointers of the rider, as for instance in the illustration, a distance of 4.45 miles on Scale B, and an angle of 17 minutes on Scale D. The difference of elevation in feet, 116, is then obtained from Scale E by reading opposite any one of the asterisks of Scale D. It will be noticed that with the same position of the slide, the angle 2° 50′ is brought opposite the pointers. The difference of elevation for this angle and the same distance is therefore read the same way, only the result is ten times as large, or 1,160 feet, which is within 2 feet of the com-

puted answer. The topographer will rarely be in doubt as to the position of the decimal point in obtaining his answer, as a glance at the topography will determine whether the result should be 116 or 1,160 feet. However, should a doubtful case arise, the correct reading may be determined readily by remembering that for any angle between 00° 03′ 30″ and 00° 34′ the difference of elevation will range from 0.001 to 0.01 times the distance in feet; likewise for angles between 00° 34′ and 05° 43′ it will range from 0.01 to 0.1 times the distance in feet, and for angles between 05° 43′ and 45° 00′ the range will be from 0.1 to 1 times the distance in feet. The positions of the asterisks will be found a great aid in remembering these points.

Attention is called to the fact that the correction for curvature, refraction, and height of instrument for the distance in question may be read off as explained under (2), without further manipulation of the instrument.

4. Given the stadia rod-reading in *feet* and the vertical angle to a point, required the difference of elevation in *feet*.

The 0° graduation of the rider is brought opposite the stadia rod-reading in feet on Scale A. Reversing the slide and having the side marked "Stadia Angles" uppermost, use it in precisely the same manner as before, reading the difference of elevation on Scale E, opposite any one of the three asterisks of Scale I. As in the preceding case the angle may occur either on the upper or lower scale of that side of the slide. The position of the decimal point may be determined again by noting that for vertical angles between 00° 03′ 30″ and 00° 34′ the difference of elevation will range from 0.001 to 0.01 times the rod-reading; for angles between 00° 34′ and 05° 46′ it will range from 0.01 to 0.1 times the rod-reading, and for angles between 05° 46′ and 45° 00′ it will range from 0.1 to ½ times the rod-reading.

5. Given the stadia rod-reading in *miles* and the vertical angle to a point, required the difference of elevation in *feet*.

The problem is the same as the preceding, except that the stadia rod-reading is in terms of miles and Scale B is to be used instead of Scale A, the remainder of the process being the same.

6. Given the stadia rod-reading and the vertical angle to a point, required the correct horizontal distance.

This problem usually occurs in connection with either of the preceding cases and may be solved without further manipulation of the rider after the latter is set for their solution.

When the rod-reading is in feet, read Scale A opposite the vertical angle in question on Scale G of the rider, marked "Cor. Hor. Dist.," the result being the *correct horizontal distance.*

When the rod-reading is in miles, note the point on Scale A opposite the vertical angle on Scale G and move the 0° graduation to it, when in so doing the pointers will be brought opposite the correct horizontal distance in miles on Scale B.

PRECISION.

The graduations on all the scales, with the exception of the one for curvature, refraction, and height of instrument, being logarithmic quantities plotted to a certain unit scale, the distances between graduations vary from point to point, requiring changes in the manner of subdividing in order to maintain clearness. The consequent result is that the precision is different for different parts of the scales, varying with the spacing of the graduations. An inspection will prove, however, that the resultant degree of precision for any particular operation of the instrument is always greatest where most required, *i.e.*, for cases of most frequent occurrence, while it is less for cases of rare occurrence. Thus, for a distance of 5.78 miles scaled from a map, and an angle of + 01° 02′, a common observation in topographic work such as is daily being done by topographers of the United States Geological Survey, the rule will give a difference of elevation of 550 feet at a point on the scale where single feet may readily be estimated, and a correction for curvature, refraction, and height of instrument of 24 feet, readily obtained without interpolation, from which the resulting difference of elevation of the point sought becomes 574 feet, *i.e.*, a result the correctness of which to the nearest foot leaves no doubt. Again, for a distance of 0.85 mile and an angle of — 6° 04′ the rule gives a difference of elevation of 477 feet, which corrected for height of instrument by the amount of 5 feet, the effect of curvature and refraction being very small for that distance, reduces the final difference of elevation to — 472 feet, a result reliable in all respects to the nearest foot.

On the other hand, cases may occur, though the exception rather than the rule, where a distance is observed of say 3.65 miles and a vertical angle of 20° 10′. The computed difference of elevation, neglecting effects of curvature and refraction, in this instance, is 7,078

feet, but the slide rule will give the result to only the nearest 10 feet, 7,070 or 7,080 feet, according to estimation. In other words, in observations of this character the rule can not be relied upon to give the answer within less than 10 feet. An error of this magnitude, however, in an observation of the kind mentioned, can not be considered serious, as the very nature of the observation is not conducive to anything more than approximate results; and it may safely be said that any topographer who carries on work of this character is doing very well if his elevations will check to within 10 feet by means of tables or by direct computation.

The range of precision attainable with the slide rule is best shown by means of the following tables :

STADIA WORK.

Distances.	Angles	Elevation reads to nearest
500 feet	up to 11° 40′	foot, estimating fractions.
	up to 26° 30′	2 feet, estimating single feet.
	up to 45° 00′	5 feet, estimating single feet.
1000 feet	up to 05° 45′	foot, estimating fractions.
	up to 11° 40′	2 feet, estimating single feet.
	up to 45° 00′	5 feet, estimating single feet.
2000 feet	up to 02° 50′	foot, estimating fractions.
	up to 05° 45′	2 feet, estimating single feet.
	up to 15° 00′	5 feet, estimating single feet.
	up to 45° 00′	10 feet, estimating single feet.

INTERSECTION WORK, (Tangents).

Distances.	Angles	Elevation reads to nearest
	up to 01° 05′	foot, estimating fractions.
	up to 02° 10′	2 feet, estimating single feet.
1 mile	up to 04° 00′	5 feet, estimating single feet.
	up to 10° 40′	10 feet, estimating single feet.
	up to 18° 30′	20 feet, estimating 2 feet.
	up to 00° 32′	foot, estimating fractions.
	up to 01° 10′	2 feet, estimating single feet.
3 miles	up to 02° 43′	5 feet, estimating single feet.
	up to 05° 25′	10 feet, estimating single feet.
	up to 10° 40′	20 feet, estimating 2 feet.
	up to 00° 13′	foot, estimating fractions.
	up to 00° 26′	2 feet, estimating single feet.
	up to 01° 05′	5 feet, estimating single feet.
5 miles	up to 02° 10′	10 feet, estimating single feet.
	up to 04° 20′	20 feet, estimating 2 feet.
	up to 10° 40′	50 feet, estimating 5 feet.
	up to 18° 30′	100 feet, estimating 10 feet.

CURVATURE, REFRACTION, AND HEIGHT OF INSTRUMENT.

Distances.	Correction reads to nearest
Up to 8.9 miles	foot, estimating fractions.
Up to 12.8 miles	2 feet, estimating single feet.
Up to 16.0 miles	5 feet, estimating single feet.
Up to 18 5 miles	10 feet, estimating single feet.

A STUDY OF HARD-PACKED SAND AND GRAVEL.

By W. O. CROSBY.

Received May 21, 1902.

A SYSTEMATIC examination, made for the Metropolitan Water Board, of the samples and accompanying notes from a large number of deep borings made with the wash-drill in the modified drift of the Nashua Valley, south of Clinton, Mass., preparatory to the construction of the North Dike, or auxiliary dam, of the Wachusett Reservoir, disclosed the fact that while much of the material was rather hard drilling, an occasional sample was labeled "hard-packed," the drillmen meaning by that term that the drill penetrated the material slowly and with difficulty. Usually only one hard-packed sample was reported from each boring, but in a few instances as many as three or four. The borings were made in a typical delta plain of glacial Lake Nashua, formed during the Clinton stage, and having a normal elevation above the sea of 360 to 380 feet.[1] This plain fills and obliterates the preglacial gorge of the Nashua River and the depth of the modified drift varies in consequence from less than one hundred to nearly three hundred feet. The entire section is composed of washed material and is prevailingly fine, — fine sand and quartz flour largely predominating. It is noticeable, however, that the hard-packed samples were reported chiefly from the head of the delta, or those points where the material averages coarsest, and they rarely occur where there is a great depth of the finer materials. The hard-packed samples vary in grade, however, from coarse gravel to quartz flour, and a classification of eighty-seven samples resulted as follows: gravel, 32; coarse and medium sand, 32; fine sand, 14; superfine sand and rock flour, 9.

[1] Geological History of the Nashua Valley during the Tertiary and Quaternary Periods. *Technology Quarterly*, Vol. xii, pp. 288–324.

In three instances only is the surface layer described as hard-packed; and, generally speaking, the hard-packed material is found only well below the local water level and yet above the level of the Nashua River below Clinton; the practical limits of the vertical range being 330 and 240 feet above the sea; while the level of the river in the lower part of Clinton is 250 feet and in Lancaster, two miles to the northward, 237 feet.

The hard-packed gravel and coarse sand is composed in large part of flat or scaly fragments of schist, mica, etc., which must have been deposited by the water in approximately parallel horizontal planes. This position, of course, offers the greatest resistance to the disturbance of the deposit by a force acting in the vertical direction; although it does not necessarily tend to prevent water from flowing through the formation freely in a horizontal direction. Practically, all the hard-packed samples above the level of the ground water, and nearly all those below the level of the Nashua River, belong to the coarse and scaly grades.

This explanation is inapplicable to the finer hard-packed samples, since they consist almost exclusively of quartz in angular and sub-angular grains; and it appears that with these finer grades of material especially the "hard-packed" condition depends chiefly upon the proportion of water which the material contains. To determine this point definitely, ten characteristic "hard-packed" samples were submitted to a series of tests as follows:

Each sample was first thoroughly dried. It was then transferred to a cylindrical vessel about two inches in diameter and two inches deep, equal to 100 cubic centimeters, and packed as closely as possible by a jarring movement. A cylindrical rod, eight millimeters in diameter, cut off squarely on the ends, representing a drill, was then rested in a vertical position upon the center of the deposit and loaded, first with a weight of approximately 15 pounds and afterwards of 75 pounds; and the depth to which the rod penetrated the sand was noted in each case.

Water was then admitted to the vessel until the sand was completely saturated, the water being accurately measured to determine the porosity of the material when as hard-packed as it could be by a prolonged jarring movement. More water was then added to completely flood the material or supersaturate it, and it was tested as before with the weighted rod.

The excess water was then drained off and blotting paper applied to the surface of the deposit under pressure for about five minutes to remove a further portion of the water, reducing the sand from a wet or saturated to a moist condition, the loss of water, or the difference between porosity and absorption, varying from three to five per cent. by volume. The penetration test with the weighted rod was again repeated. The results of all the tests are given in the accompanying table, and the figures prove conclusively, what is of course roughly a matter of common observation, that the moist sand is much firmer and more hard-packed than either the dry or the very wet sand. The explanation is found in the fact that while in the saturated sand the water acts as a lubricant between the grains, in the moist sand it is insufficient to fill the interstices and the surface tension of the water causes it to act as a cement, binding the grains together. Above the level of the ground water, except in wet weather, the sand probably contains insufficient water to serve this purpose, and below the general drainage level of the valley it contains too much. It is obvious from this explanation that the "hard-packed" condition has little bearing upon the question of the relative perviousness of the sands or the flow of the ground water through them; but it usually occurs where a relatively fine-grained layer is enclosed between coarser beds or grades horizontally into coarse and pervious materials which permit the excess water to drain away.

It is a fair conclusion that the hard-packed condition is indicative of a high degree of porosity, or at least of a free movement of water through the deposit. This is in harmony with the proposed explanation, with the distribution of the hard-packed borings, the vertical distribution of the hard-packed samples, and their prevailing coarse and pervious character. It is interesting to note the comparatively slight variations in the porosity of the different grades of sand, the extremes being 36 and 43 per cent. The figures show very plainly that in most cases the vessel was not large enough to give the full effective contrast, as regards penetration, between the dry and saturated, and the moist states; but the use of a larger vessel was impracticable on account of the small size of the samples. It is noticeable, too, that this contrast is greatest for the finer grades, which show also the maximum porosity, indicating uniformity of grain or a low uniformity coefficient.

Neither the samples nor the notes afford evidence that the material

PENETRATION TESTS WITH TYPICAL HARD PACKED SAMPLES.

	Elevation.				Grade of Fineness.*			Depth of Penetration in Inches.						Porosity in Per Cents.
								Dry.		Saturated.		Moist.		
	Surface.	Bed Rock.	Ground Water.	Hard-packed Layer.	Hard-packed Layer.	Over-lying Layer.	Under-lying Layer.	Min.	Max.	Min.	Max.	Min.	Max.	
1.	368.6	284.9	337.5	316.5 — 311.0	5	2	6	1.35	1.80	0.75	1.40	0.50	1.10	
2.	384.0	297.8	334.6	328.3 — 312.2	3-4	4-5	6 (h)	1.90	1.90	0.85	1.75	0.50	1.10	36
3.	384.0	297.8	334.6	312.2 — 297.8	6	3-4 (h)	Rock	1.90	1.95	1.45	1.70	0.15	1.05	39
4.	381.6	275.2	340.4	275.2 — 272.5	6	4	Rock	1.85	1.95	1.90	1.95	0.25	1.25	42
5.	345.4	219.8	333.3	229.8 — 224.1	5	2 (h)	2-3(h)	1.70	1.90	0.50	1.25	0.35	0.90	40
6.	380.6	244.0	334.9	321.2 — 290.9	5	7	2 (h)	1.80	1.90	1.60	1.90	0.35	0.75	40
7.	364.8	209.1	333.1	230.1 — 209.1	3	2 (h)	Rock	1.90	1.90	0.90	1.70	0.70	1.55	40
8.	382.7	209.1	331.8	324.3 — 305.4	6-7	5	6 (h)	1.75	1.80	1.50	1.70	0.02	0.50	42.5
9.	382.7	209.1	331.8	305.4 — 265.7	6	6-7 (h)	Rock	1.75	1.90	1.90	1.95	0.35	1.50	43
10.	347.3	151.0	336.9	260.6 — 151.0	7	7	2	1.90	1.95	1.85	1.95	0.02	0.80	42

(*) 1 = coarse gravel; 2 = fine gravel; 3 = coarse sand; 4 = medium sand; 5 = fine sand; 6 = superfine sand; 7 = quartz flour.

(h) Hard-packed Material.

is "hard-packed" from the presence of clay or because it has been exceptionally well settled and the grains of different sizes crowded closely together. The general conclusion is rather, as stated: either the material is scaly in form, or it contains insufficient water to fill the pores, or these conditions co-exist. According to this explanation, the water supplied by the drill must tend to escape into the ground in hard-packed layers, and this has been commonly observed, but in no case has the material been described as hard-packed simply because of the clogging of the drill consequent upon loss of water. On the contrary, the real test of hard-packed sand or gravel is the fact that it resists the free impact of the drill, be the loss of water great or small.

SMOKE AND ITS ABATEMENT IN LARGE CITIES.

By C. H. BENJAMIN.

Read April 10, 1902.

At first thought it seems strange that a denizen of Cleveland, that smoky city of the middle west, should venture to appear before a Boston audience and talk about the abatement of smoke. It must however be admitted that experience, though a dear teacher, is an efficient one, and that where smoke is and that in abundance, one may learn all the more thoroughly of its production and its abatement.

The air of your city seems clear and pure to one who comes from the smoke-laden atmosphere of cities in the soft coal belt. The fact that this evil has made so little progress in Boston is all the more reason why immediate measures should be taken to prevent any further encroachments. It is enough to know that the danger is already present, and that it would only be a matter of years to make the conditions here as unsatisfactory as those in Cleveland or Chicago. You have now this great advantage, that you are acting mainly on the defensive, trying to check the spread of this nuisance, while we in Cleveland have been suffering from its effects for the past twenty-five years, and have only now really begun to fight intelligently; we have to act the offensive and try and drive out that which is already with us.

You will pardon me if I devote a few minutes to the consideration of the nature of soft coal smoke. The smoke from bituminous coal owes its offensive character to the presence of hydrocarbons in that grade of fuel. Coals such as anthracite and semi-bituminous, which are free from hydrogen, or nearly so, cause little offense. When bituminous coal is first thrown upon a hot fire the heat distills from the fresh fuel the volatile hydrocarbons which would pass off as an almost colorless gas if unburned. The heat and the presence of a certain amount of oxygen causes these gases to burn with a yellow flame. If sufficient air is supplied, and the temperature is not

allowed to fall, they will be almost completely burned, and no objectionable smoke will result. If however, the quantity of air is insufficient, or if the gases be chilled by coming into contact with the comparatively cold surface of the boiler, combustion is retarded, and fine particles are set free, which either collect on the cold surfaces as soot, or pass off through the chimney as black smoke. It is extremely difficult to burn this soot after it is once formed, and the better remedy is prevention. The peculiar oily consistency of the soot from this class of coals is probably due to the presence of hydrogen with the carbon.

From what has been said, it will be readily understood that black

FIG. 1.—TWO SMOKY MILL STACKS; SEVEN GRATES FOR EACH STACK, 1901. Now equipped with stokers.

smoke indicates imperfect combustion, while its prevention means a perfect burning of the fuel and consequent economy. The immediate cause of smoke from hand-fired furnaces is the fact that a large quantity of fresh coal thrown on the fire clogs up the air passages, and thus causes a scarcity of oxygen at the very time when it is most needed. When the fire is incandescent and burning brightly, if the draft is good, sufficient air will pass through the grate to complete the burning of both the gaseous and solid parts of the fuel. If this condition could be maintained permanently there would be no trouble from smoke. This is the result which the mechanical stoker aims to accomplish. The feeding of coal uniformly along the grate, keeping the fire of proper thickness, and maintaining the conditions as to coal

and air supply uniform, gives ideal conditions for economical burning of the fuel. Another device in common use is the down-draft furnace, having two grates where the fresh coal is fed to the upper, and the air draft is down through the fire upon that grate to the lower. All the volatile products mixed with the air from the draft are thus obliged to pass through an intensely hot fire on their way to the chimney, and are completely burned. The use of fire brick arches and checker work maintained at a white heat will also help to complete the burning of the gases which pass under or through them. Where ordinary flat grates are used, fired by hand at irregular intervals, it is necessary to in some way vary the air supply to correspond.

FIG. 2.— A MILL OF A STEEL WORKS IN 1901.
Beginning to install smoke preventers in 1902.

From what has been said, it is evident that this additional air needed just after firing cannot be supplied from below; it is accordingly introduced above the grate through the door, or through flues at the sides of the furnace, being either drawn in by the action of steam-jets, or forced in by blower. The air or steam is turned on by the opening of the fire door, and shut off after a suitable interval by a dash pot or other automatic contrivance. It must be understood that the steam-jet probably takes no part in the combustion, but acts simply to create an induced draft, and to thoroughly mix the incoming air with the burning gases. We have been taught in the past that air used in this way should be preheated. Experience with air-regulat-

ing apparatus in Cleveland has shown that this is not the case; if the air is supplied in a proper quantity, the heat arising from the immediate combustion which takes place, raises rather than lowers the temperature of the fire. Of course, if too much air were introduced, loss would result. In the matter of efficiency and economy, the blower is probably superior to the steam-jet. Were this all the story, progress in smoke abatement would be even slower than it is. Fortunately economy in fuel is a natural result of prevention of smoke. Any manufacturer who is allowing black smoke to come from his chimney can save from ten to twenty-five per cent. on his fuel account by stopping that smoke. This has been proved so many times

FIG. 3.—BOILER PLANT OF A SALT COMPANY AS IT WAS IN 1901.
Now in process of change, 1902.

that it is no longer open to argument. I have seen this demonstration repeatedly, not only by expert tests covering from one to six days, but also by a comparison of fuel bills for the month and for the year; how great the saving will depend upon how bad were the former conditions.

And now just a word as to the legal aspect of this subject. It is undoubtedly possible for your Commonwealth to enact stringent laws, making the production of smoke a misdemeanor, and providing for penalties in case of noncompliance with the law. In fact, such a law is necessary as a prelude to any successful work. The law once in your hands, it behooves you to be careful how you use it, — used

FIG. 4. — TWO LARGE STACKS OF A STREET RAILWAY COMPANY.

Under the first one the boilers are equipped with mechanical stokers, under the other they are hand fired.

FIG. 5. — A STEEL MILL.

There are two boilers to each stack. All eight boilers were fired at the same time with the same amount and kind of coal. Those under one stack are equipped with smoke preventers. Which one is it?

recklessly and without discernment it may do more harm than good. A policy of enforcement of a law of this kind which is oppressive and injudicious in its character, will result in such ill feeling and opposition as will defeat its own ends. Smoke producers, as a rule, are not of the criminal class; they may be selfish and thoughtless of the rights of others, but they are usually human beings very much like the rest of us. They do not incommode their neighbors and prejudice the community out of malice or hardness of heart. Treat them as gentlemen and as business men, and they will usually do their best to remedy the difficulty.

Now the one all-potent argument in such cases is the saving in

FIG. 6.—STACK OF AN ELECTRIC LIGHT PLANT.

Equipped with underfeed stokers in 1901 and now comparatively clean.

fuel which will result from a compliance with the law. The immediate expense is sometimes large, a good stoker costing nearly as much as the boiler under which it is located, but a manufacturer or business man will be quick to see that a saving of even ten per cent. in fuel will pay a remarkably good interest on the cost of any stoker.

The problem on the railroads is a somewhat different one. The application of mechanical stokers to locomotive engines is as yet an experiment, and has not met with much success. We are reduced to two alternatives, either the use of smokeless fuel, or to such careful firing as will reduce to a minimum the smoke from soft coal. In Boston, I believe, you have the former policy; in Cleveland at present

we are following the latter. I would describe to you briefly the manner of carrying out the work of smoke abatement in our city.

We first ascertain the conditions at each establishment, the number of boilers used, kind of furnace, and kind of fuel, in other words we make a complete census of the furnaces of the city and put this into card index form. We do the same with the locomotives on the railroads. To determine where the smoke is, and where it is not, we make careful observations on each chimney or engine, taking readings at short intervals, and averaging a large number of observations on which to base a report. We are thus enabled to know the relative standing of each firm or road in this matter. The subject is then presented to those having control in each place, and advice and instructions are given as to the best remedy. Legal measures have not been used so far; the campaign has been one of education and moral suasion. We have received to a very large extent the coöperation of manufacturers and of railroad men, and have made marked progress by this method of work. Cleveland has been, and is, a very smoky city, and the conditions at times are discouraging, since we are at all times fighting not the coming evil, but one which is already with us; that under these circumstances a decided improvement has been made in a period of eighteen months, is cause for encouragement.

The proposition then presents itself under these heads. First, the smoke from soft coal is a great damage to property and to health; second, it is entirely practicable to prevent the greater part of the smoke coming from this class of fuel; third, such prevention will not only result in good to the community at large, but in direct personal profit to the individual most directly interested. With very few exceptions, all the new power plants in our city are equipped as they are built, with satisfactory smoke-preventing devices. If you in your city will see to it that this is the case here, you will have little cause for fear in the future.

THE MICROSCOPIC EXAMINATION OF PAPER FIBRES.

By W. R. WHITNEY and A. G. WOODMAN.

Received June 6, 1902.

The examination of the fibres of paper to determine the nature and the source of the raw material is a matter of considerable importance not only to those directly interested in paper manufacture, but to the analytical chemist who may be called upon to take up the question with only slight previous knowledge of the subject.

For the determination of the nature of the fibres the microscope is usually relied upon, being the simplest and readiest means, but its use in this connection, no easy matter even to those of experience, is rendered doubly difficult by the scarcity of accurate descriptions and figures for reference, especially the latter. Some drawings and photographs of the more common fibres are available, but drawings are usually too much idealized to be of the greatest assistance to one unacquainted with the characteristic features. Furthermore, the best reproductions of photographs, such as those by Herzberg in "Papier Prüfung" and Rostaing in "Photomicrographie des Vegetaux," which are most excellent so far as they go, are accompanied only by German or French text.

It is proposed to supply this want by the accompanying photographic reproductions and descriptions which include many fibres not available in published works. No attempt has been made to give a careful or at all complete study of structure or botanical characteristics, but simply the enumeration of certain features which are most apparent and the description of certain differences which seem best suited to distinguish one fibre from another.

The apparatus required is very simple, a comparatively inexpensive microscope giving magnifications up to 60 diameters being the important thing. One giving higher powers may be useful at times but it is not essential. On account of the transparent nature of many of the

mounted fibres it is almost necessary, however, that the microscope be fitted with the requisite apparatus for viewing objects by polarized light. The ordinary microscope slides and cover glasses are employed in mounting permanent specimens.

In order to prepare the material for examination pieces taken from various portions of the paper are torn into small bits. These are boiled for a few minutes in a one-per-cent. solution of caustic soda, then the pulpy mass is poured on a fine sieve, about 100 meshes to the linear inch, and washed with water until practically free from alkali. The pulp is transferred to a bottle half filled with water and shaken vigorously to break up any lumps. The addition of glass beads or garnets to assist in this shaking, as recommended by some, is to be avoided on account of the danger of destroying the delicate cells which accompany some fibres and serve for their identification. In some cases, however, in order to separate the fibres well it may be necessary to fray them gently in a mortar. For a temporary examination the fibres are mounted in water or a mixture of glycerine and water, while slides for permanent record may be prepared in any of the usual ways with agar, glycerine jelly, or Canada balsam. Several slides should be prepared at the same time and examined in order to be sure that none of the various cell-forms which may be present in the pulp shall escape observation. Often the most characteristic cells or fibres in the case of some paper stocks are present only in very small quantities and may not appear at all in a particular mounted specimen of that stock.

In examining the slides, which should be done systematically and carefully by both direct and polarized light, the following points should be noted:

(1) Fibres — size, length, diameter or width relative to the length, shape of the end, presence of knots and joints, whether the majority of the fibres are straight or bent or curled, markings on the fibre, size and character of the central canal, if any, any changes in color on rotating the polarizer or analyzer, etc.

(2) Forms other than fibres — size, shape, width as compared to length, markings, shape and length of the ends.

Some of these points will, in most cases, be sufficiently characteristic to enable the fibre to be identified with considerable certainty.

It should be borne in mind in this connection that the chemical and mechanical treatment to which the fibre is subjected in the manu-

facture of the paper may obliterate these characteristics to a certain extent so that the process of identification is not so easy as in the case of the raw material. It can generally be done, however, with sufficient study.

As occasion offers, typical specimens both of the pulped and of the mounted fibres should be prepared and preserved for reference and subsequent comparison. Some standard magnification should be adopted and all prepared alike in order to show the differences more readily.

By reference to the following scheme, in which the fibres are classified according to their most prominent characteristics, the question of identity may be narrowed down to three or four fibres, the exact identification being established by reference to the detailed description accompanying the plates. The number preceding the name of the fibre refers to the page on which the description may be found, those following it to the illustrative figures. In all cases the appearance of the majority of the fibres must serve as a guide, since the same slide may show marked differences even in fibres from the same source. Where there seemed to be a possibility of confusion the fibre has been given more than one place in the scheme.

ANALYTICAL SCHEME.

A. Fibres are characteristic; other characteristic forms absent.

I. Fibres are *long*; greater than diameter of field (Mag. = 60).

(1) Fibre has many joints, knots or projections, especially by polarized light.

(*a*) Fibre is fine; quite smooth; joints not very noticeable.

(276) *Paper mulberry* — 1, 2; (277) *Manila hemp* — 3; (277) *Agave* — 4.

(*b*) Fibre is coarse, uneven; joints are large and prominent.

(277) *Linen* — 5–8; (279) *Jute* — 9, 10; (279) *Hemp* (*Cannabis sativa*) — 11, 12.

(*c*) Fibre shows over-lapping scales.

(281) *Wool* — 13, 14.

(2) Fibre has peculiar markings; dotted, circular, square, net-like.

(*a*) Markings resemble circular or square perforations.

(281) *Spruce*, (*fir, hemlock, tamarack, balsam*) — 15–20; (283) *Pine* — 21–23. (283) *Redwood* — 24, 25; (285) *Red cedar* — 26; (285) *Arbor vitæ* — 27; (285) *Cypress* — 28, 29.

(*b*) Markings net-like, "feather-stitch," spiral.

(283) *Redwood* — 24, 25; (285) *Cypress* — 28, 29; (285) *Banana* (*fruit stem*) — 32; (287) *Ramie* — 33.

(3) Fibre is smooth and regular.

(*a*) Many fibres resemble twisted ribbons.

(287) *Cotton* — 34–37; (287) *Banana* (*stalk and leaf stem*) — 30, 31.

(*b*) Fibres are round, cylindrical.

(287) *Silk* — 38; (289) *Sisal hemp* — 39, 40; (289) *Bark of cotton stalk* — 41.

II. Fibres are *short;* less than diameter of field (Mag. = 60).
(1) Ends of fibres frayed and torn.
(289) *Cotton rag* — 42, 43; (289) *Mechanical wood* (conifers) — 44.
(2) Ends of fibres not torn.
(291) *Coir* — 45; (291) *Elm* — 46; (305) *Willow* — 80.

B. Characteristic forms other than fibres are also present.
I. Fibres are *long;* equal to or greater than diameter of field (Mag. = 60).
(1) Fibres quite broad in middle; tapering to point like a bayonet.
(*a*) One or both ends of cells drawn out, sometimes terminating in a tail.
(291) *Poplar* — 47, 48; (291) *Birch* — 49–51; (293) *Porpor gum* — 52.
(*b*) Ends of cells cut off obliquely at blunt angle.
(293) *Cotton wood* — 53; (295) *White wood* — 54; (295) *Black walnut* — 55; (301) *Holly* — 73; (303) *Chestnut* 74.
(2) Fibres not varying greatly in width, ends needle-like.
(*a*) Characteristic forms (cells) *large;* covering $\frac{1}{4}$ to $\frac{1}{3}$ diameter of field.
(295) *Bamboo* — 56; (297) *Sorghum bagasse* — 57, 58; (297) *Raffia* — 59; (301) *Tulip* — 70.
(*b*) Characteristic forms *small*, cellular, serrated, or pointed.
(297) *Straw* — 60–62; (299) *Esparto* — 63–65; (299) *Sugar cane bagasse* — 66; (299) *Live Oak* — 67.
II. Fibres are *short;* less than diameter of field (Mag. = 60).
(1) Cells comparatively long and narrow; quite sharply pointed at one or both ends.
(299) *Magnolia* — 68, 69; (301) *Tulip* — 70; (301) *Sweet buckeye* — 71, 72.
(2) Cells prismatic, stubby; ends blunt and cut off obliquely.
(*a*) Quantities of short, fine, transparent material with square ends.
(301) *Holly* — 73; (303) *Chestnut* — 74.
(*b*) Field fairly clear except for fibres and characteristic elements.
(303) *Pawpaw* — 75; (303) *Tree of Heaven* — 76; (303) *Maple* — 77, 78; (305) *Black Cherry* — 79; (305) *Willow* — 80.
(3) Cells fragmentary, broken; fibres short.
(305) *Ground wood* — 81, 82; (291) *Elm* — 46.

The following reproductions[1] were made from slides prepared in most cases from the paper itself. In a number of cases fibres are shown which have no practical utility in paper-making, owing to scarcity of the material, cost of treatment, etc. The hard woods, for example, have not shown themselves well adapted for paper-making. It must be borne in mind that a single field under the microscope seldom contains all the characteristic fibres and cells of the material under examination; some selection was, therefore, necessary in case of the following photographs. They represent, however, the actual appearance in each case of a certain field under the microscope, and the idealizing which tends to creep into drawings made from the microscope, is at least confined in this case to the text.

[1] The magnifications given under the illustrations are those of the original photographs The plates are all reduced to four-fifths of the original diameters.

PAPER MULBERRY. (*Broussonetia papyrifera.*) Figures 1, 2.

The fibres are long, slender, varying in length from 6 to 20 millimeters with an average diameter of .030 millimeter. By direct light

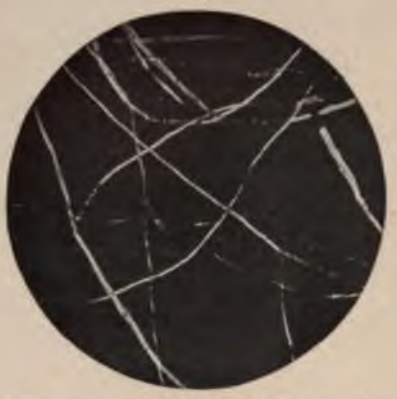


FIG. 1.—MULBERRY JAPANESE PAPER.
Polarized Light. × 60.

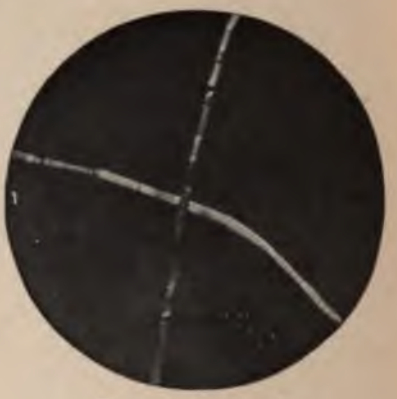


FIG. 2.—MULBERRY.
Polarized Light. × 180.

FIG. 3.—MANILA.
Polarized Light. × 60.

FIG. 4.—CENTURY PLANT.
Polarized Light. × 60.

they are nearly transparent, and by polarized light appear as white, lustrous cords. The fibres vary considerably in diameter, and constrictions of the same fibre at irregular intervals are common. Longitudinal striæ as well as transverse jointings are shown. The latter appear especially well in the enlarged view (Figure 2). The ends are

sometimes blunt and rounded, sometimes fringed. The central canal usually shows as a well-defined line. The fibres are smoother and more regular than those of manila hemp or the century plant.

MANILA HEMP. (*Musa textilis.*) Figure 3.

The average length of the fibres is about 6 millimeters, the diameter .024 millimeter. The fibres are usually white and lustrous and show a play of colors varying from dark brown to steel-blue on rotating the analyzer. The central canal is large and very apparent. The fine cross-markings or canals running from the central canal to the walls are numerous and prominent. The fibres taper very gradually and regularly toward the ends; they are generally shorter and much coarser or harsher than either mulberry or century plant. The best qualities of manila wrapping paper are made of this fibre; a cheaper grade of manila wrapping paper is made from the fibre after it has passed a useful life as rope, twine, and heavy bagging; and from other materials such as jute. Some grades of so-called manila contain some hemp, with various quantities of chemical wood pulp. Some contain no manila at all, and in some the cheap ground wood is a prominent constituent.

CENTURY PLANT. (AMERICAN ALOE.) (*Agave americana.*) Figure 4.

The fibres are long, of rather small diameter, tapering and pointed at the ends. They vary considerably in diameter in different fibres. The central canal is not very prominent, but can be seen as a narrow black line in some of the individual fibres. Knots and joints occur at irregular, but quite frequent, intervals. The fibre is characterized by the great number of very fine cross lines close together which are noticeable in nearly every specimen. (Figure 4*a*.) The fibres are harsher than mulberry, resembling manila in this respect, but are longer than the latter.

LINEN. (CULTIVATED FLAX.) (*Linum usitatissimum.*) Figures 5–8.

Linen consists of the ultimate fibres of the flax plant, what is ordinarily called flax being bundles of fibres as shown in Figure 5. These ultimate fibres are 25 to 30 millimeters long and .020 millimeter in diameter. They resemble thick-walled tubes, the central canal, on

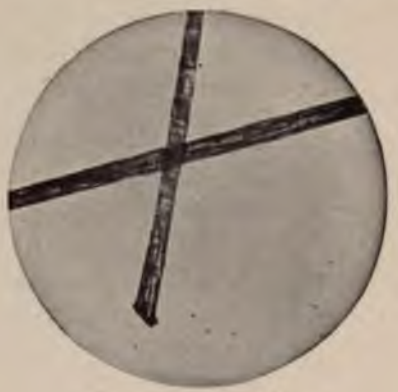


FIG. 5.—FLAX. × 60.

FIG. 6.—LINEN. × 60.

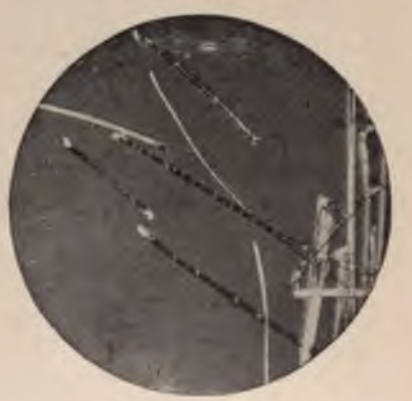


FIG. 7.—LINEN.
Polarized Light. × 60.

FIG. 8.—LINEN. × 180.

FIG. 9.—JUTE. × 60.

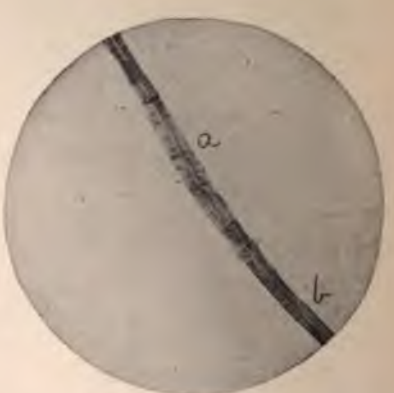


FIG. 10.—JUTE. × 180.

account of the relative thickness of the walls, often showing merely as a dark line (Figure 6*a*). From this central canal numerous ducts pass to the outside, showing under the microscope as slender cross markings. (Figure 8*a*.) The most characteristic feature, however, is the knotting or jointing of the fibre at quite regular intervals, as is well shown in Figures 6 and 7.

This is the material of which the finest grades of writing paper are always said to be made. It is true, however, that a pure linen paper is not very common. The good grades of writing paper which contain linen usually also contain some cotton, while many of the so-called linen papers contain only cotton or cotton and chemical wood.

JUTE. (*Corchorus capsularis* and *C. olitorius*.) Figures 9, 10.

Jute consists of typical bast fibres about 2 millimeters long and .022 millimeter in diameter. The fibres are long, quite smooth, and often compacted into bundles. The chief characteristic of the jute fibre is the varying thickness of the cell wall, which often passes from one extreme to the other within the limits of the microscopic field. The central canal at times appears of considerable width, then, owing to the increased thickness of the walls, it narrows until even with high magnifications it is visible only as a fine line and may even disappear entirely. This effect may be repeated in its entirety at short intervals, as in Figure 10, *a* and *b*. It should be borne in mind, however, that these changes are not shown by every fibre and it is sometimes necessary to follow a single fibre quite a distance to note the variations in thickness of the cell wall. The difficulty in recognizing the fibres is increased at times by the fact that they are gathered or compacted into bundles, in which case one fibre may lie across another and hide its characteristic features. At intervals will be noticed the radial canals and the joints which may be distinguished readily from the rest of the fibre by their different color. The joints bear a strong resemblance to the same features of the linen fibres, except that they are not so pronounced. The chief difference, however, is in the central canal.

HEMP. (*Cannabis sativa*.) Figures 11, 12.

The structure of the hemp fibre closely resembles that of linen and the distinction between them is a difficult and at times impossible one to make. The fibre shows the same knots, the same broadened

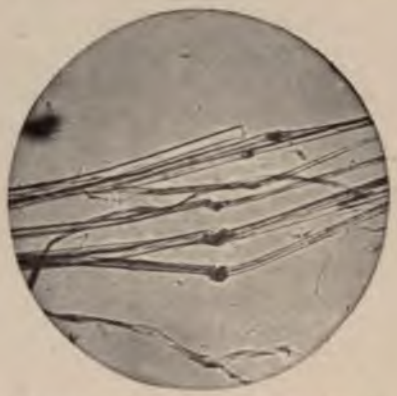


FIG. 11. — HEMP. (*Cannabis sativa.*) × 60.

FIG. 12. — HEMP. (*Cannabis sativa*) Polarized Light. × 60.

FIG. 13. — WOOL. × 60.

FIG. 14. — WOOL. × 180.

FIG. 15. — SPRUCE. Polarized Light. × 60.

FIG. 16. — JAPANESE SPRUCE. Bleached Sulphite. Polarized Light. × 60.

portions, the same ragged ends as does linen. The chief difference consists in the character of the central canal, which is broader and takes up a greater portion of the diameter of the fibre, and in the presence of longitudinal striations.

The fibres are long, about 22 millimeters, with a diameter of .022 millimeter, straighter and coarser than linen. They show swellings and bendings as in Figure 11.

Wool. Figures 13, 14.

While wool is not, strictly speaking, a paper fibre, it finds some use in decorative papers and it has seemed best to include it that the series may be more nearly complete. The fibre, which is usually much curled and twisted, is characterized by its broken surface, being covered with minute overlapping scales like roof-tiles, which cause the felting or matting together of the fibres in the process of manufacture. These scales are clearly shown in Figure 14. The fibres are usually very long, curled, and the ends are abrupt, showing simple rupture or cutting of the fibres.

Spruce. (*Picea nigra.*) Figures 15, 16.

The spruce fibres may be taken as typical of those of coniferous trees. The fibres, which are almost entirely tracheïds, are broad and flat. The ends are sometimes very pointed, sometimes blunt and rounded. In mechanical spruce they are usually frayed and torn (Figure 44). The fibres are often twisted somewhat like those of cotton, as shown in Figure 15, and still more clearly in Figure 19. The twist in this case is, however, easily distinguished from that of cotton, as it is usually abrupt in the former and is the result of rough treatment of the fibre, while it is gradual in the cotton and the result of growth. They are characterized by the presence of numerous pitted cells or cups (Figures 20 and 44), most of which are circular, while some are more or less elliptical. These latter are more apparent in sulphite pulp. By polarized light the pits appear as black dots on the fibre (Figure 16). The larger, squarish holes, penetrating through the fibre, which are so characteristic of pine, are entirely absent in spruce.

FIG. 17.—FIR. Unbleached Sulphite. Polarized Light. × 60.

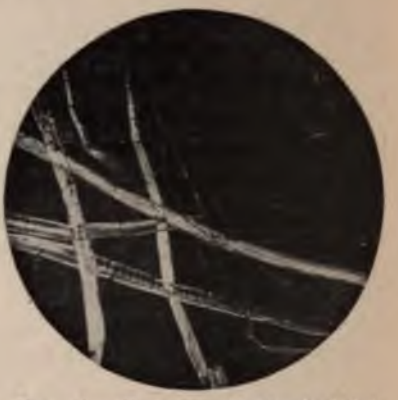


FIG. 18.—BALSAM. Unbleached Sulphite. Polarized Light. × 60.

FIG. 19.—TAMARACK. Bleached Sulphite. Polarized Light. × 60.

FIG. 20.—HEMLOCK. Unbleached. × 60.

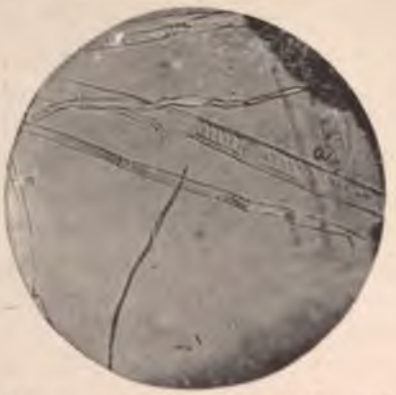


FIG. 21.—NORWAY PINE. Unbleached Sulphite. Polarized Light. × 60.

FIG. 22.—SODA PINE. × 60.

FIR. (*Abies grandis.*)	Figure 17.
BALSAM. (*Abies fraseri.*)	Figure 18.
TAMARACK, LARCH. (*Larix americana.*)	Figure 19.
HEMLOCK. (*Tanga canadensis.*)	Figure 20.

These fibres so closely resemble spruce that it is practically impossible in most cases to distinguish them with any certainty. They are usually classed with the spruce and pine under the caption "cone bearers." The great length and strength of the fibres make them the most useful component of cheap paper, such as newspaper. A very large proportion of magazine paper contains these fibres mixed with other material, such as poplar and cotton rag.

PINE. (*Pinus strobus, P. banksiana*, etc.) Figures 21–23.

The fibres of pine vary in length, from 3 to 4 millimeters being a fair average, and are much broader than most other paper fibres. They resemble most closely in shape and size the fibres of spruce and fir. Each end is usually very gradually tapered to a point. The fibres are generally flat and not twisted at all. Single rows of circular markings (Figure 21*a*) occur at intervals on most of the fibres, which in this respect are very similar to those of spruce. Pine has, however, another characteristic which is not so frequent as the circular discoid markings. This is the group of oblong openings, usually five or six in number, which in distinction to the circular markings, penetrate through the fibre. They are very characteristic and afford a ready means for identifying the pine fibre.

REDWOOD. (*Sequoia sempervirens.*) Figures 24, 25.

Two kinds of fibres are noticeable, a broad, flat fibre with rounded, spatulate ends, and a narrower rounded fibre with longer, more pointed ends. The broad fibres have several rows of small circular markings, appearing as black dots by polarized light, scattered more or less regularly over the fibre. The other fibres are marked by transverse pores appearing as short, black lines placed at an acute angle with the main axis of the fibre, the general effect being that of "feather stitching." The fibre is easily distinguished from spruce and pine by having several rows of the discoid markings and by the presence of the narrow fibres.

FIG. 23 — SODA PINE. × 180.

FIG. 24. — REDWOOD. × 60.

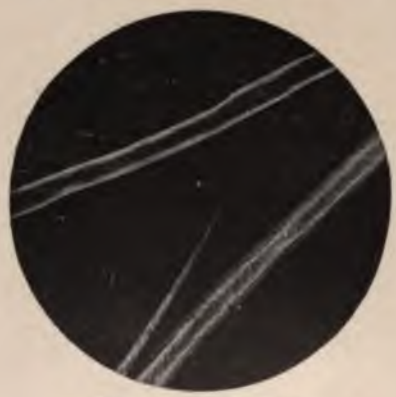


FIG. 25. — REDWOOD.
Polarized Light. × 60.

FIG. 26. — RED CEDAR.
Polarized Light × 60.

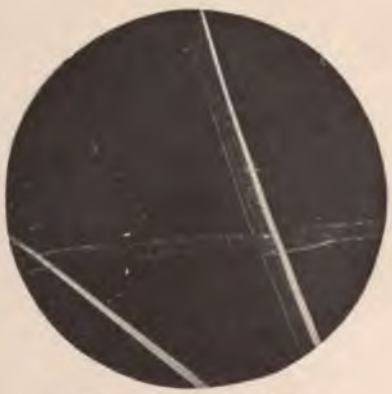


FIG. 27. — ARBOR VITÆ.
Polarized Light. × 60.

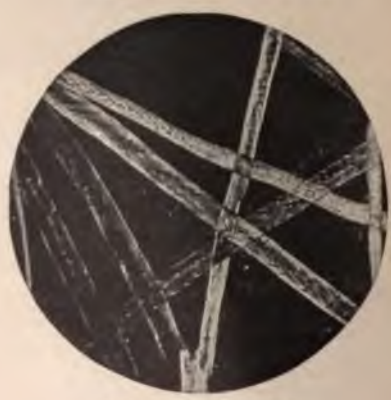


FIG. 28. — CYPRESS.
Polarized Light. × 60.

RED CEDAR. (*Juniperus Virginiana.*) Figure 26.

The fibres are long and slender with bluntly pointed ends. Some are straight and others bent or broken; they are of fairly uniform diameter, and are characterized by markings on the fibre. In some cases these show as one or two rows of dots parallel to the axis of the fibre, in others occur the crisscross or "feather stitch" markings. These markings closely resemble those of redwood or cypress; the fibres are, however, much smaller than either of the latter.

ARBOR VITÆ. (*Thuja occidentalis.*) Figure 27.

The fibres are long, smooth, and straight, much resembling red cedar and redwood, but intermediate in size between the two and not so distinctly marked. They are very transparent, even by polarized light, and many are of a bright steel-blue color when viewed in this way. Rows of dots are present as in red cedar; the crisscross markings, however, are only slight, and observed with some difficulty in few fibres.

CYPRESS. (*Taxodium distichum.*) Figures 28, 29.

The description given for redwood applies almost equally well to cypress, the only practical difference being that the cypress fibres are smaller and the pores on the broad fibres are not so large nor prominent. The best method of differentiation would be the comparison of size with standard slides of redwood, cypress, and possibly arbor vitæ and red cedar.

BANANA. (*Musa sapientum.*) Figures 30–32.

The fibres of the banana are characterized under the microscope by the mass of curled and tangled filaments that may be seen (Figure 30). Some of these resemble fine curled hair, others broad, thin bands of ribbon. The same fibre may show both features at different portions of its length, sometimes changing from one extreme to the other within the limits of the microscopic field. The curling of the fibres may be carried so far that some of them are coiled repeatedly upon themselves. The ends are often very fine and delicate. Some of the broader fibres show reticulated markings. The fibres from the *leaf stem* (Figure 31) show the same general characteristics except that there is

FIG. 29. — CYPRESS. × 60.

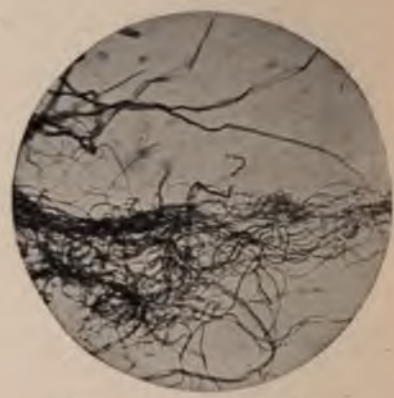


FIG. 30. — BANANA. × 60.

FIG. 31. — BANANA LEAF STEM. × 60.

FIG. 32. — BANANA FRUIT STEM. × 60.

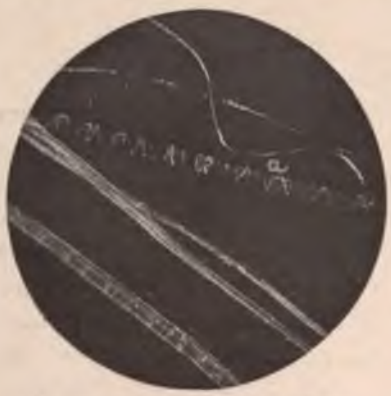


FIG. 33. — RAMIE. CHINA GRASS. Polarized Light. × 60.

FIG. 34. — MERCERIZED COTTON. × 60.

not quite so much of the very fine material and the crinkliness of the fibre is not so marked. In the case of the fibres from the *fruit stem* there is comparatively little of the fine curly material. The fibres are shorter, broad, with tapering ends, sometimes spatulate. The markings on the fibres show distinctly as at *a* in Figure 32.

RAMIE. CHINA GRASS. (*Bœhmeria nivea.*) Figure 33.

Ramie presents long, smooth, stiff fibres, which are lustrous and show brilliant colors, especially by polarized light. They are generally cylindrical and may be either smooth or striated. The central canal is well developed. By polarized light the peculiar spiral markings (Figure 33*a*) are plainly visible.

COTTON. (*Gossypium.*) Figures 34–37.

The cotton fibre is usually extremely long, varying from 20 to 50 millimeters; the breadth varies from .012 to .037 millimeter. Only a small portion of the fibre is included within the microscopic field. The fibres are very characteristic, being flattened like a collapsed tube and twisted spirally. This flattening is not seen in the unripened fibre, which is a tube filled with liquid protoplasmic matter. The ends are somewhat narrowed and rounded. In mercerized cotton the fibre is more compacted, not so flat, and the spiral twisting is less noticeable. (Figure 36.) In Figure 37 is shown the appearance of cottonseed lint, characterized by the torn, square ends of the fibre. Cotton forms the basis of most medium grade papers. The greater part of most high grade book paper, card board, blotting paper, etc., is made of cotton rag.

SILK. Figure 38.

The silk fibres resemble glistening, transparent, cylindrical rods which are generally smooth and regular, but at times may appear to be twisted and may show irregularities of outline. There are no joints noticeable. Some varieties, especially by polarized light, show various colors ranging from yellowish brown to deep blue. No apparent structure is to be observed; the fibres appear like threads of glass.

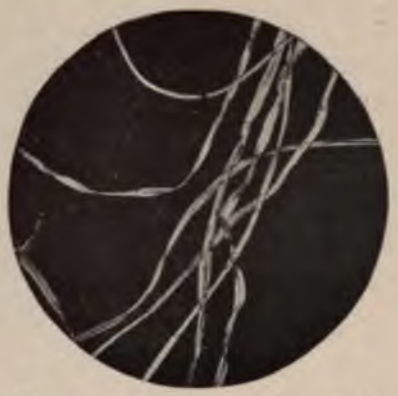


FIG. 35. — COTTON. Long Staple American Carded. Polarized Light. × 60.

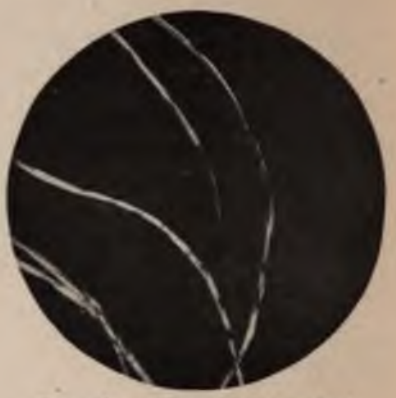


FIG. 36. — COTTON. Mercerized. (Same Sample as in Fig. 35.) × 60.

FIG. 37. — COTTON SEED LINT. × 60.

FIG. 38. — SILK. Polarized Light. × 60.

FIG. 39. — SISAL. × 60.

FIG. 40. SISAL. × 180.

SISAL HEMP. (*Agave ixli.*) Figures 39, 40.

Sisal hemp, which is derived from a species of *Agave*, should not be confounded with true hemp, *Cannabis sativa.* The fibres are smooth, with thick walls, and taper gradually at the ends to a point. The central canal is very large and conspicuous. (Figure 40.) The fibres can be distinguished readily from silk by the structure and the pointed ends, and from the bast fibres of the cotton stalk by their greater length and freedom from twisting.

BARK FROM THE COTTON STALK. Figure 41.

In distinction from the seed hairs which are usually spoken of as the cotton fibre, a fine jute-like bast fibre may be separated from the bark of the stalk. These fibres show only slightly the twisting so characteristic of the ordinary cotton fibre; they are much shorter, more nearly round, and taper toward the ends. The central canal appears as a black line.

COTTON RAG. (*From paper.*) Figures 42, 43.

The fibres show the general characteristics of the cotton fibres as regards structure, but are much shorter and the ends are much frayed and torn, owing to the mechanical treatment to which the fibres have been subjected.

MECHANICAL WOOD. (*Conifers.*) Figure 44.

The general remarks made concerning cotton rag apply to mechanical wood. The fibres are characterized by their shortness, irregularity, and broken, frayed, and torn ends. The fibres are irregular since much of the ligneous matter still remains, not having been dissolved out by chemical agents, and though most of the fibres are badly mangled, usually enough of the characteristic features remain to distinguish the source of the wood. Thus in Figure 44 the discoid markings at *a* show the wood to be spruce and in Figure 81 the peculiar cells show the sample to be poplar. Mechanical wood usually shows masses of the medullary rays, which in the trunk extend from the centre to the circumference in the form of a star. These show as a lattice or trellis-work, more or less distinct, as in Figure 82. (See also Figure 84.)

FIG. 41. — BARK FROM COTTON STALK.
× 60.

FIG. 42. — RAG.
× 60.

FIG. 43. — COTTON RAG.
Polarized Light. × 60.

FIG. 44. — MECHANICAL SPRUCE.
Polarized Light. × 60.

FIG. 45. — COIR.
× 60.

FIG. 46. — WHITE ELM.
Polarized Light. × 60.

COIR. (*Cocos nucifera.*) Figure 45.

Coir, known also as Kair, is the fibre of the husk surrounding the cocoa nut. The fibres are short, stiff and quite smooth, tapering gradually to the ends, which are rounded. The central canal is very marked.

ELM. (*Ulmus Americana.*) Figure 46.

The fibres are short, of fairly uniform diameter, not tapering. Some are straight and offer no special characteristic; most of them, however, are curled and bent in a very striking manner. The cells, which are few, are fragmentary and not very noticeable, so that the fibre may be placed by different observers under either Class A or B.

POPLAR. (*Populus grandidentata.*) Figures 47, 48.

The ligneous fibres of poplar are very similar to those of birch and are hardly to be distinguished from them. At times will be noticed rather narrow fibres with joints. (Figure 47*a*.) The large cells distinct from the plain, narrow fibres serve to distinguish poplar readily from birch, however. These are less numerous and show large open pores like honeycomb (Figures 47 and 48). The ends of the cells often extend for some distance in the form of a tail. (Figure 47*b*.) The lateral or transversal ends marked in the form of a grating, which characterize birch, are entirely absent. These peculiar cells showing such characteristic markings enable one to recognize the presence of poplar, birch, willow, etc., where this would be difficult or impossible if one had to depend on the simple ligneous fibres, which differ but little in the different woods. These marked cells are entirely absent from the conifers. This fibre and the following soft woods are used to a very great extent in newspaper and cheap book paper. It has not the length nor strength of the coniferous fibres, and some of the latter is, therefore, usually mixed with the poplar in the paper.

BIRCH. (*Betula alba, B. papyrifera.*) Figures 49–51.

The birch fibres are long, with walls which are sometimes narrow and again quite thickened; in the latter feature they are similar to straw. In birch, however, the constrictions of the central canal caused by the thickening of the walls are uncolored, while in straw

FIG. 47. — POPLAR. Digester Stock. × 60.

FIG. 48. — POPLAR. Rotary Stock. × 60.

FIG. 49. — BIRCH. × 60.

FIG. 50. — CANOE BIRCH. Polarized Light. × 60.

FIG. 51. — BIRCH. Polarized Light. × 60.

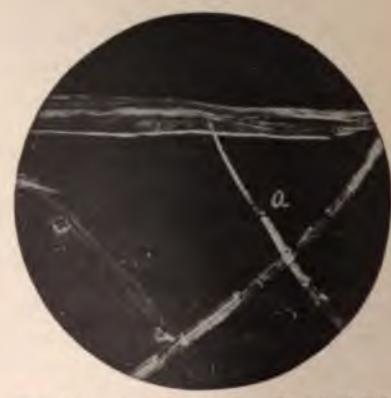


FIG. 52. — PORPOR GUM. Bleached Sulphite. Polarized Light. × 60.

they are often reddish brown. Some of the fibres which have a large central cavity and narrow walls also show small canals extending in various directions from the centre to the circumference. Some of the fibres have rounded ends; the majority, however, are pointed in the shape of a bayonet. (Figure 50*a*.) The cells, which are very noticeable, exhibit numerous markings in the form of slits, often placed obliquely to the main axis. (Figure 50*b*.) These are sometimes distributed regularly in the cell; sometimes many are grouped at one place, while a little further on there are none, and this alternation may be reproduced four or five times in a single cell. (Figure 51.) At the end of the cell shown in Figure 51 can be seen clearly the transverse wall marked like a net or a grating. Birch usually shows a number of these characteristic cells. The net work marking on these birch cells is much finer than the markings of the corresponding poplar cells.

PORPOR GUM. Figure 52.

The fibres are long and quite wide in the centre, tapering to a bayonet point at the ends. Many of them are jointed at regular intervals, often bending or changing the direction of the fibre as at *a*, Figure 52. The tapering usually does not extend beyond the joint nearest the end. The numerous cross markings, like canals, extending from the circumference toward the centre are shown in the figure. The cells, which are quite numerous, are long and slender, narrowed at the ends, and characterized by parallel rows of pores resembling cross-bars. There are usually several ranks of these, arranged parallel to the main axis of the cell.

COTTONWOOD. (*Populus deltoides*, syn. *P. monilifera.*) Figure 53.

The fibres of the cottonwood are long, ribbon-like; broad in the middle and tapering gradually to a sharp bayonet point at the ends. The fibre is often twisted on its axis and frequently bent at quite sharp angles, sometimes in several places in the same fibre, either in the same general direction or alternately in opposite directions. The joints, which are numerous, are not swellings or knots, but are more like V-shaped cuts in the fibre. Small pores or canals extending from the centre to the circumference are numerous. The cells are very large and coarse. The ends are cut off obliquely, sometimes

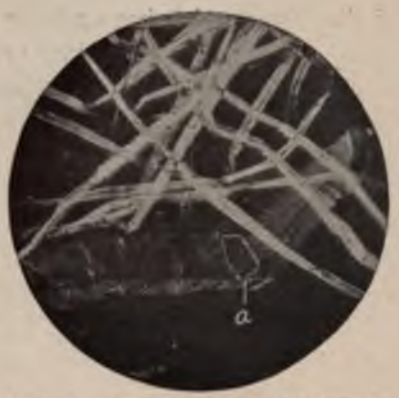


FIG. 53. — COTTONWOOD. Unbleached Sulphite. Polarized Light. × 60.

FIG. 54. — WHITEWOOD. Polarized Light. × 60.

FIG. 55. — BLACK WALNUT. Polarized Light. × 60.

FIG. 56. — BAMBOO. Polarized Light. × 60.

FIG. 57. — SORGHUM BAGASSE. Polarized Light. × 60.

FIG. 58. — SORGHUM BAGASSE. Polarized Light. × 60.

appearing nearly square in section (Figure 53*a*), once in a while with a small prolongation. There are no special markings on the end. The cell ordinarily appears as two sides of a rectangular prism, one side having large pores like a honeycomb or more resembling square paving blocks set some distance apart, the other side being smooth and often without any markings. Occasionally the smoother side may show at intervals sets of cross markings two or three in number, as if the paving block marking extended across it in narrow bands. This may be repeated three or four times in the length of a cell.

WHITEWOOD. Figure 54.

The fibres are fairly long, averaging a little more than the diameter of the field (× 60), broad in the middle and tapering to a well defined bayonet point, as at *a* in Figure 54. The cells are quite large and long in proportion to their width. They are somewhat similar to cottonwood but are smaller, the ends are more blunt and do not have the slight prolongation present in cottonwood. Some show markings on the end similar to those of birch.

BLACK WALNUT. (*Juglans nigra.*) Figure 55.

The fibres are long, mostly straight and quite regular; a few are jointed. Some are blunt or squarish at the ends as if broken; the majority, however, taper to a bayonet point at the ends. The cells, which are few in number, are of fairly good size but short and blunt; their ends are usually cut off obliquely, one ordinarily at a sharper angle than the other. The markings are not distributed with any regularity and are not especially characteristic.

BAMBOO. (*Bambusa arundinacea.*) Figure 56.

The length of the bamboo fibre varies from 6 to 10 millimeters; its diameter is about .015 millimeter. Its microscopical characteristics are in general those of straw. The fibres are twisted and curled upon one another, sometimes showing as a complete ring. The walls are thick, the central canal being prominent and well defined. Ovoid pith cells with characteristic markings, a good example of which is shown in Figure 56, occur, together with serrated cells similar to those in straw and esparto.

FIG. 59. — RAFFIA.
× 60.

FIG. 60. — STRAW PULP.
Polarized Light. × 60.

FIG. 61. — STRAW.
× 60.

FIG. 62. — STRAW. Polarized Light.
× 180.

FIG. 63. — ESPARTO.
× 60.

FIG. 64. — SPANISH ESPARTO.
Polarized Light. × 60.

SORGHUM BAGASSE. (*Sorghum vulgare.*) Figures 57, 58.

The fibre much resembles that of straw, being clear and nearly transparent, even by polarized light. There is considerable variation in diameter, as is shown even by those in Figure 58. The walls are thin and the central canal large and prominent. The jointing is very marked and the fibre is usually bent at the joint, sometimes successively in the same direction, sometimes alternately in different directions, as in Figure 57. The ends are pointed. The characteristic cells, which are not very numerous, are shown fairly well in the figures. They are cylindrical, with cross markings like parallel ridges, usually arranged in two or three rows parallel to the main axis.

RAFFIA. (*Raphia ruffia.*) Figure 59.

Raffia consists of fibres from the leaf stalk of a species of palm, *Raphia ruffia*, which grows in Madagascar. The fibres are round, long, and smooth with a tendency to curl. By polarized light the central cavity shows as a well-defined black line and small cross markings at irregular intervals may be observed. Occasionally will be seen one of the characteristic masses of cellular tissue. (Figure 59*a*.) These have no definite outline and appear simply as aggregations of cells, approximately circular in outline, closely grouped together.

STRAW. (*Gramineæ spp.*) Figures 60–62.

The straw fibres present considerable variation in size as derived from different sources. They are in general long and slender, having a fairly uniform diameter for a given fibre. At quite regular intervals occurs a sort of jointing, as if the walls were thickened and drawn together. A characteristic feature of straw pulp is the occurrence of serrated epidermal cells, as shown in Figure 60*a* and enlarged in Figure 62. These vary considerably in size and also in dimensions, the ratio of length to width varying from 1:1 to 10:1. Similar cells are found in esparto but they are smaller. Another characteristic feature is the presence of smooth pith cells. (Figure 61.) These vary in shape from nearly circular or oval to a more elongated form; the width, however, is usually great in proportion to the length. They occur at times separately or joined in series like links of sausages. These pith cells are absent from esparto. Other elements

FIG. 65.—ESPARTO. × 180.

FIG. 66.—SUGAR CANE BAGASSE. × 60.

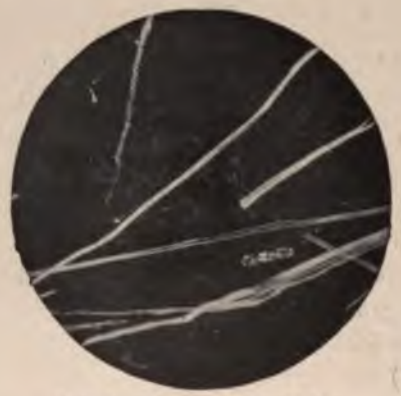


FIG. 67.—LIVE OAK. × 60.

FIG. 68.—MAGNOLIA ACUMINATA. × 60.

FIG. 69.—MAGNOLIA FRASERI. × 60.

FIG. 70.—TULIP TREE. × 60.

more or less characteristic sometimes occur, but these are the most frequent and distinctive.

ESPARTO. (*Stipa tenacissima.*) Figures 63–65.

The fibres of esparto resemble those of straw, but are smaller and more even. Most of them are long, but a few are short. The average length is about 1.5 millimeters, the diameter, about .012 millimeter. Serrated epidermal cells resembling those of straw are common ; they are, however, considerably smaller as will be seen by comparing Figures 60 and 63. Another feature serving to distinguish esparto from straw is the occurrence of small tear-shaped cells, shown at *a* and *b*, Figure 64. The smooth pith cells found in straw pulp are commonly absent from esparto.

SUGAR CANE BAGASSE. (*Saccharum officinarum.*) Figure 66.

The fibres differ considerably, some being narrow and rounded, others broad, flat, and ribbon-like. The ends are mainly pointed, some are blunt as if broken off. Some of the fibres are twisted like cotton but are much shorter. There is great variation in the size of the fibres and some of the small ones have a tendency to curl like the banana fibre, even forming coils and rings, as at *a*, Figure 66. Pith cells are numerous. These may be smooth and flat as shown in the figure, or long, resembling a sausage casing ; at other times they may be short and thick, much resembling the pith cells of straw. The fibre is readily distinguished from straw, however, by the lack of the prominent joints.

LIVE OAK (*Quercus virens.*) Figure 67.

The fibres are slender, of medium length, with blunt ends. They do not taper. Masses of nearly transparent fragments of the medullary rays are common. Sausage shaped links of small cells occur.

MAGNOLIA. (*Magnolia acuminata, M. Fraseri.*) Figures 68, 69.

The fibres of magnolia are short, resembling those of the tulip tree. They are rather broader, however, and not so tapering at the ends. The fibre is rougher, harsher, and shows greater tendency to

FIG. 71. — SWEET BUCKEYE. × 60.

FIG. 72. — SWEET BUCKEYE. × 60.

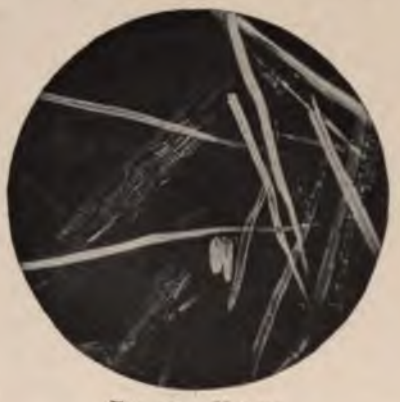


FIG. 73. — HOLLY.
× 60.

FIG. 74. — CHESTNUT.
Polarized Light. × 60.

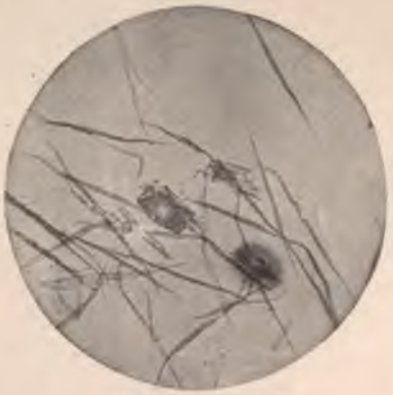


FIG. 75. — PAWPAW.
× 60.

FIG. 76. — TREE OF HEAVEN.
Polarized Light. × 60.

fraying at the ends. In many of the fibres a peculiar "feather-stitch" marking is noticeable. The cells, which are about the same size as those of tulip, are narrower and are of two general forms. One kind has a partition or line running lengthwise and cross-markings at intervals like the bars of a gridiron. (Figure 68*a*) The ends are cut off slantwise and show markings where the longitudinal septa emerge. The others, which seem fairly characteristic of *M. Fraseri*, are long and narrow with one or two prominent longitudinal lines. (Figure 69.) The surface seems covered with large cellular markings which are quite different from the gridiron markings of *M. acuminata*.

TULIP TREE. (*Liriodendron tulipifera.*) Figure 70.

The fibres are short, broad and tapering to a point at the ends. The cells are numerous and characteristic. They are not very long compared with the width and are divided longitudinally by septa which show as lines on the ends. The ends are roundly pointed and cut off at a slight angle. The pores are large, open, and regularly arranged as at *a*. Longitudinal creases or folds are quite marked.

SWEET BUCKEYE. (*Æsculus flava.*) Figures 71, 72.

The fibres are short, not so long as those of tulip and not so short as pawpaw. The cells are of small size but long in proportion to the width, roughly about 6 or 8 to 1. They are more pointed at the ends than in tulip and the marks on the end are absent. Cells in which five or six short rectangular cross bars occur are common. (Figure 72.)

HOLLY. (*Ilex opaca.*) Figure 73.

The fibres of holly are of medium length, covering about the diameter of the field (× 60), although many are much shorter. They are quite straight, narrowing to a sharp pointed end, in many cases to a "bayonet" point. The cells are large, prismatic, transparent, with several longitudinally parallel series of cross markings. The pulp contains a great proportion of short, nearly transparent material with practically square ends. Some of the bits are nearly as broad as long; they show by polarized light a row of dots running lengthwise through the middle.

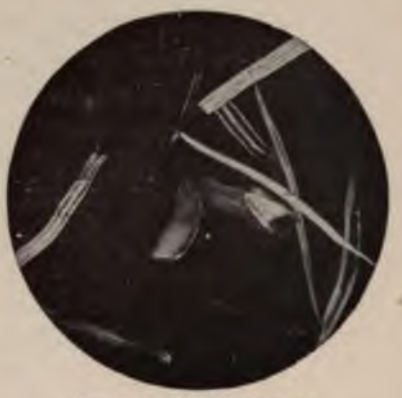


FIG. 77.—CURLY MAPLE.
Polarized Light. × 60.

FIG. 78.—SUGAR MAPLE. Bleached Sulphite. Polarized Light. × 60.

FIG 79.—BLACK CHERRY.
Polarized Light. × 60.

FIG. 80.—WILLOW.
× 60.

FIG. 81.—GROUND WOOD.
Polarized Light. × 60.

FIG. 82.—MECHANICAL WOOD.
Polarized Light. × 60.

CHESTNUT. (*Castanea vesca.*) Figure 74.

The fibres are for the most part short, nearly straight, transparent even by polarized light. The ends are tapering but not sharply defined. The cells are few, transparent and not especially characteristic. There is a great quantity of transparent material similar to that described under holly, varying in length from nearly the diameter of the field to a length not much greater than the breadth. Many are joined side by side.

PAWPAW. (*Asimina triloba.*) Figure 75.

The fibres of pawpaw are very short and pointed like small double-pointed wooden toothpicks. They are much shorter than tulip. The cells are not very numerous. They are very short and blunt, the length being not much greater than the width. The ends are oblique and at a slight angle with each other. The pores are numerous, small, and close together.

TREE OF HEAVEN. (*Ailantus glandulosus.*) Figure 76.

The fibres are short and tapering from the centre toward each end. They are broad in proportion to the length. The ends are sharply pointed. Some of the fibres show a play of colors from brown to bright blue as the analyzer is rotated. There are also peculiar characteristic masses as shown in Figure 76; large, irregular in shape, usually squarish, with large square markings resembling paving blocks.

MAPLE. (*Acer spp.*) Figures 77, 78.

The maple fibres are mostly short, tapering toward the ends, in some cases with a "bayonet" point. Some of the ends are broken or frayed. The cells are numerous and of several kinds. One kind (Figure 78), prismatic, with large open pores, is very similar to cottonwood but considerably smaller. Some (Figure 77) are short and dumpy, the narrowing toward the ends beginning near the middle. A few of the cells have chisel-shape ends. The markings are large, coarse, open, like square paving blocks. Still another kind is almost exactly like those of sorghum bagasse. (Figure 58.)

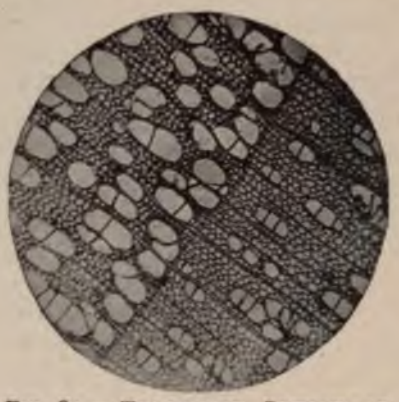


FIG. 83. — TRANSVERSE SECTION OF QUAKING ASP. × 60.

FIG. 84. — RADIAL SECTION OF QUAKING ASP. × 60.

FIG. 85. — TANGENTIAL SECTION OF QUAKING ASP. × 60.

FIG. 86. — TRANSVERSE SECTION OF BLACK SPRUCE. Polarized Light. × 60.

FIG. 87. — RADIAL SECTION OF BLACK SPRUCE. Polarized Light. × 60.

FIG. 88. — TANGENTIAL SECTION OF BLACK SPRUCE. Polarized Light. × 60.

BLACK CHERRY. (*Prunus serotina.*) Figure 79.

The fibres are short with ends bluntly pointed, usually torn or split into two or three jagged points at the ends. The cells are numerous, of medium size, transparent, with the ends cut off obliquely, giving a triangular appearance.

WILLOW. (*Salix spp.*) Figure 80.

The fibres of willow are very short, resembling those of pawpaw, but with a greater number of the broader ones which do not taper to so sharp a point. The two kinds are present in both pawpaw and willow pulp, but the second kind is more numerous in willow. The cells, which are very few, are larger than those of pawpaw; they are short and broad with slanting ends. (See Figure 93.)

MECHANICAL WOOD. (Leaf-bearing trees.) Figures 81, 82.

The description of mechanical wood on page 289 applies also in this case, the principal difference being in the presence of the characteristic cells which in many cases serve to distinguish the source of the pulp.

In connection with the wood fibres it has further seemed of interest to add a few illustrations, showing the way in which the various elements used to distinguish the fibres actually occur in the wood during the process of growth. This is readily shown by the examination of thin sections cut from the wood in certain directions.

As typical of the leaf-bearing trees may be taken the QUAKING ASP, (*Populus tremuloides*). Figures 83–85.

Transverse section. (Figure 83.) In this the large openings which are shown are the cells. It will be noticed that these are larger and more open in one part of the field than in the other, this being a difference between the spring and the autumnal growth. The lines crossing the cells are the divisional septa, which in the pulp show as lines on the ends of the cells. The larger parallel lines running across the field are the medullary rays.

Radial section. (Figure 84.) This section shows the *cells* in the midst of the fibres and also the *medullary rays* at right angles to the fibres like a lattice-work.

FIG. 89. — SECTION OF SUGAR MAPLE. × 60.

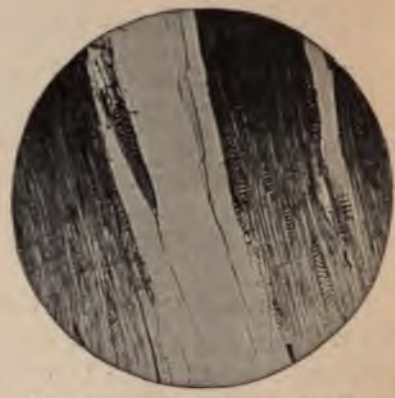


FIG. 90. — SECTION OF WHITE ELM. × 60.

FIG. 91. — SECTION OF WHITE BIRCH. × 60.

FIG. 92. — SECTION OF WHITE ASH. × 60.

FIG. 93. — SECTION OF YELLOW WILLOW. Polarized Light. × 60.

FIG. 94. — SECTION OF BASSWOOD. Polarized Light. × 60.

Tangential section (Figure 85). The [illegible] are clearly shown together with a view edge-wise of the medullary rays [illegible]

The sections of BLACK SPRUCE, *Picea nigra*, Figures 85–88, may be considered typical of [illegible]

The ***transverse section*** (Figure 86) shows still more clearly the compression of spaces in autumnal as compared with the spring growth. The medullary rays are also clearly shown.

In the ***radial section*** (Figure 87) are shown the fibres with circular discoid markings or cups (*a*), which show as crosses by polarized light.

The ***tangential section*** (Figure 88) shows the medullary rays and also the fibres, viewed edgewise, exhibiting depressions, which are the cups that resemble discoid markings in other positions of the fibre.

Further views of some of these characteristic features are also given in some of the other sections. (Figures 89–94.)

CONTRIBUTIONS FROM THE LABORATORY OF SANITARY CHEMISTRY.

V.

NOTES ON OSCILLARIA PROLIFICA (*Greville*).

BY ISABEL F. HYAMS AND ELLEN H. RICHARDS.

SECOND PAPER: CHEMICAL COMPOSITION.

IN close connection with the life history of the plant as presented in the previous paper[1] is its chemical composition and that of the water in which it grows.

As in other relations, so in this, the plant under consideration may be considered a type of the class of blue-green algæ, of which one or other members causes much trouble both at the waterworks and to the consumer; and some knowledge of the type may lead to a generalization of value in dealing with the class, — for this reason the study has been continued. There are other and more general deductions to be drawn from the circumstances of growth and decay which will be discussed in later papers.

The analysis of the plant as made and reported in a paper, an abstract of which was published in the Proceedings of the American Association for the Advancement of Science,[2] is given in the following table in connection with others made subsequently.

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[1] Contributions from the Laboratory of Sanitary Chemistry. IV. TECHNOLOGY QUARTERLY, Vol. xiv, No. 4, December, 1901.

[2] 1898, p. 234.

TABLE I. PARTIAL ANALYSES OF DRIED OSCILLARIA. PER CENT.

1898.	No.	SiO_2.	Fe_2O_3. Al_2O_3.	P_2O_5.	SO_3.	N.	CaO.	MgO.	ASH.	MOISTURE.
	1	.32	—	1.07	1.75	11.0	0.35	0.13	3.37	—
	2	—	—	1.00	1.75	10.3	—	—	—	—
1900										
Young, green		1.46	.40	.89	—	9.00	—	—	4.50	—
1901										
Mature, brown		2.90	.50	.54	—	7.90	—	—	6.1 6.7	—
One year old [1]		2.82	2.12	—	—	—	0.35	0.33	6.7	8.4
Portion of old.		—	—	0 38	0.46	—	—	—	—	4.5
Two years old		1.29	—	—	—	—	—	—	—	—
		1 21	—	—	—	—	—	—	—	—
		—	—	0.47	0.49	—	—	—	—	—

TABLE II. ANALYSIS OF THE WATER AT SURFACE. Parts per 100,000.

1901.	SiO_2.	Fe_2O_3. Al_2O_3.	MnO.	CaO.	MgO.	SO_3.	Cl.
June at 50 feet.	.436	.070	.015	1.31	.55	1.09	.90
August.						.56	
1902. May.	.380	.093	.011	1.38	.51	1.05	.86

[1] This sample contained also Mn_3O_4, 0.20; K_2O, 0.57; Na_2O, 2.6.

The proportion of silica seems very high and with some other characteristics indicates an approach to the condition found in diatoms. This large amount of silica accounts for the remarkable stability of the framework or tissue of the plant which persists the year around in heat and cold, a tissue so characteristic that there is no mistaking it under the microscope whatever the character of the cell-contents may be. These contents vary in amount, in color, and in chemical characteristics. Only one seems constant and that is the colorless saponin-

like substance which is set free to such an extent that the water froths whenever stirred by the wind as if it contained a liberal supply of soap bark. This substance surrounds the fibres like a jelly and causes them to adhere to stones and to form clots.

Especial interest attaches to that portion of the cell-contents which is concerned in the vital activity of the plant, — the protoplasm and that which corresponds to chorophyll. The interest is only increased by the changes in color from dull to bright blue-green and to reddish-brown and bright purple. We have proved that there is a real substance having a red color depending on its chemical composition, and not, as has been assumed, resulting from "the refraction due to the presence of large numbers of gas vacuoles as suggested by Kleban."[1]

A discussion of the chemical character of this and other substances extracted from the plant will form the subject of the next paper.

During the year 1901, determinations of phosphates in the water were made at intervals by Mr. A. G. Woodman, with the result that while the clear water contained as a rule 3.7 parts per million (P_2O_5), when the growth was at its height all traces of phosphates had disappeared.

During the same year, 1901, almost daily determinations of carbon-dioxide dissolved in the water were made from March to October.

To summarize the result, it may be said that the upper layers of water held about five parts per million, the usual amount in surface waters, but whenever the Oscillaria grew vigorously, this carbon-dioxide disappeared and the water became not only neutral but alkaline. With the decay of the plant, the alkalinity disappeared and carbon-dioxide again became normal and in one or two instances appeared in excess. Owing to the peculiarities of the season, this change took place several times. An abundant growth of Oscillaria appeared in August of that year, but in the water of so high a temperature it showed itself in large clots held by its own gelatinous envelope and the color was a light dirty green. In four other ponds infested with Anabæna, the same phenomenon of alkalinity in the period of growth was observed.

Thus it may be said that the presence of phosphates and carbonic

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[1] Dr. G. T. Moore. Soc. for Plant Morphology, *Science*, 1900.

acid, as well as of nitrogen, are at least favoring conditions for increase.

Whether this plant is able to take free nitrogen from the air or only from ammonia and nitrates in the water has not been determined.

In the case under consideration there is enough present in the water as will be seen from the following table of analyses, compiled from the Massachusetts State Board of Health Reports to 1895 and from our own work of later date.[1]

TABLE III. ANALYSES OF WATER FROM JAMAICA POND.

PERIOD OF HIGH FREE AMMONIA. (PARTS IN 100,000.)

Date.	Free Ammonia.	Total Alb Ammonia.	Chlorine.	Nitrates.
1887.				
Dec. 2	.0475	.0336	78	0060
1888.				
Jan. 11	.0346	.0277	88	.0180
Feb. 1	.0324	.0258	88	.0200
March 1	.0438	.0269	86	.0150
April 3	.0352	.0278	81	.0100
Nov. 1	.0272	.0482	85	.0250
Dec. 4	.0300	.0476	82	.0300
1889.				
Jan. 2	.0344	.0480	84	.0380
Feb. 5	.0240	.0620	81	.0280
Dec. 3	.0504	.0218	—	.0380
1890.				
Jan. 3	.0356	.0310	—	.0400
Feb. 4	.0192	.0266	—	.0400
1891.				
Jan. 24	.0600	.0240	—	.0300
Feb. 24	.0360	.0288	79	.0380
April 7	.0152	.0252	—	.0600
1898.				
April 10	.0362	.0691	86	.0600
1900.				
April 5	.0216	.0496	83	.0250
May 8	.0240	.0518	87	.0400
1902.				
Jan. 2	.0300	.0205	84	.0250

[1] Amer. Pub. Health Asso., Vol. 27, 411, 467. 1901.

PERIOD OF LOW FREE AMMONIA. (PARTS IN 100,000.)

Date.	Free Ammonia.	Total Alb. Ammonia.	Chlorine.	Nitrates.
1887.				
Sept. 2	.0000	.0279	85	.0000
Oct. 4	.0007	.0263	85	.0000
1888.				
July 11	.0002	.0240	83	.0020
Sept. 5	.0000	.0376	82	.0020
Oct. 2	.0000	.0460	79	.0050
1889.				
April 3	.0008	.0616	82	.0500
May 2	.0000	.0990	84	.0250
June 5	.0000	.1600	83	.0030
July 2	.0002	.0534	—	.0020
Sept. 4	.0004	.0266	—	.0040
Oct. 3	.0010	.0264	—	.0030
Nov. 6	.0090	.0196	—	.0120
1890.				
March 4	.0032	.0226	88	.0380
April 2	.0004	.0364	84	.0550
July 2	.0060	.0254	82	.0110
1891.				
April 29	.0000	.0330	—	.0700
May 27	.0054	.0268	76	.0500
June 29	.0000	.0304	—	.0300
Aug. 6	.0000	.0234	—	.0020
1892.				
Oct. 29	.0002	.0228	79	.0050
1897.				
Oct. 29	.0002	.0432	86	.0070
1898.				
May 5	.0010	.1200	84	.0100
1899.				
Oct. 20	.0002	.0248	—	.0000
1900.				
May 8	.0024	.0518	87	.0400
June 1	.0014	.0406	—	.0000
Aug. 2	.0013	.0262	82	.0080
Oct. 9	.0054	.0120	81	.0020
1901.				
May 13	.0002	.0268	—	.0300
Oct. 13	.0009	.0250	—	.0070

WATER NEAR BOTTOM, 40 TO 50 FEET FROM SURFACE. (PARTS IN 100,000.)

Date.	Free.	Alb. Ammonia.	Chlorine	Nitrates.	Iron.
1889.					
July 25	.3880	.0228		.0050	
Oct. 30	.7680	.0510		.0030	
Dec. 26	.0464	.0182		.0320	
1890.					
Feb. 17	.0118	.0166		.0300	
March 26	.0004	.0136		.0500	
April 17	.0048	.0148		.0480	
April 29	.0800	.0190		.0280	
May 29	.2200	.0260		.0060	
July 18	.4480	.2000		.0070	
July 31	.6870	.0310		.0080	
Oct. 1	.5000	.0270		.0150	
Nov. 13	.1600	.0218		.0150	
Dec. 2	.0600	.0244		.0200	
1891.					
Jan. 24	.0640	.0236		.0320	
Feb. 24	.0464	.0234	79	.0400	
April 7	.0184	.0286	—	.0600	
(Lowest this year)					
1892.					
Oct. 29	.4420	.0956	78	.0000	.4100
1894.					
Aug. 22	.6080	.0536	94	.0040	.6000
1901.					
Aug. 6	.3500	.0680		.0030	.2250

The amount of fresh food material brought in by the brook during the past fifteen years has been considerable, but on the other hand, the removal of several houses, of the ice houses with their stables, together with the care of the surface by the Park Commission must all have tended to a lessening of soil contamination in the immediate vicinity. The average underground water is also shown in a series of analyses of water within a few hundred feet of the pond.

TABLE IV. WELLS NEAR JAMAICA POND. (PARTS IN 100,000.)

Locality.	Date.	Physical. Color.	Turbidity.	Sediment.	Odor. Cold.	Hot.	Residue on Evaporation. Total.	Loss on Ignition.	Fixed.	Nitrogen as Alb. Ammonia. Total.	Free Ammonia.	Nitrites.	Nitrates.	Hardness.	Chlorine.	Remarks.
Center St.	1892.	0	0	0	Dist.	Dist.	—			.0006	.0020	0001	.3500	5.7	2.00	Said to be fed from Pond.
Eliot St., Smith.	1893.	0	0	0	0	0				.0018	.0006	.0001	.1500	--	1.76	
Park Dept., Cool	1893.	0	0	V. sl.	0	0	12.80			.0668	.0014	.0013	.3000	5.6	1.18	
Dr. Jameson.	1898.						14.30			.0000	0000	.0000	.5000	5.8	2.34	

BROOK FLOWING INTO JAMAICA POND. (PARTS IN 100,000.)

Date.	Physical. Color.	Turbidity.	Sediment.	Odor. Cold.	Hot.	Residue on Evaporation. Total.	Loss on Ignition.	Fixed.	Nitrogen as Alb. Ammonia. Total.	Free Ammonia.	Nitrites.	Nitrates.	Hardness.	Chlorine.	Remarks.
1900, April 27.	.15	None.	Cons.	Earthy.		12.80			.0326	.0015	.0020	.1500	4.8	.92	
1901, April 3.									.0274	.0060	.0015	.3000	—	.90	
1901, May 13.	.22	Dist.	Cons.	——		10.30	2.30	8.00	.0356	.0100	.0020	.1100	4.6	.83	
1901, August 2.									.0482	.0006	.0020	.0900	—	1.20	Cœlospherium in abundance.
1901, October 10.									.0430	.0040	.0025	.0550	—	—	
1902, May 12.									.0248	.0104	.0006	.0600	—	.96	

According to Professor W. O. Crosby, this body of water is supposed to lie in a "kettle hole" in modified drift or in a basin formed by the melting of a block of ice left in the ground in the progress of surface modifications by glacial action.

NOTE: — The year 1902 has brought no recurrence of the "blooming" time of Oscillaria in the water. There are several circumstances which have influenced this; first, abnormally high temperature in March and April which started the growth at an earlier date than ever before; second, protracted cool weather in June and July with exceptionally high winds which kept the water stirred to a considerable depth — only once in the whole season and that on a morning with cold, heavy fog, has the surface been still since April until August.

Another factor has been the introduction of a flock of ducks and a pair of swans. Whether they have fed upon the plant or whether they have cleared out the mosquito larvæ which were formerly more abundant than this year and which might furnish food by decay, or whether their influence has been nil, cannot be determined. Certain it is that the absence of the former abundant growth, so thick as to make the water opaque, has permitted the fish to thrive. Not since 1886 has the water been so thick with small fry as during this July.

BOOK REVIEWS.

CHURCH'S DIAGRAMS.[1]

IN spite of the numerous criticisms that have been launched at Kutter's formula for computing the flow of water in open channels, the fact that it has been increasingly used in this country for nearly a quarter of a century shows that it has great merit. The necessary uncertainty, however, generally attending the selection of the very important "coefficient of roughness" renders the results to be obtained from diagrams of moderate size practically as satisfactory as those from numerical computation; while the rather complex shape of the formula has from the first led to its being applied graphically, for mere economy's sake.

Professor Church's diagrams are six by eight inches in size, and eleven in number. Each diagram shows, with sufficient exactness, for some one value of Kutter's coefficient of roughness, the varying relations between slope of channel, hydraulic radius, and mean velocity. Those values of the coefficient most likely to be used in engineering practice are included, the whole set ranging from 0.009 to 0.035.

By aid of these diagrams, problems as to the carrying capacity, proper dimensions, or necessary slope, of sewers, aqueducts, canals, and other channels may be quickly solved; and the high reputation of the author for careful and exact work gives one confidence that the diagrams have been accurately prepared.

DWIGHT PORTER.

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[1] Diagrams of Mean Velocity of Uniform Motion of Water in Open Channels, based on the Formula of Ganguillet and Kutter. By Irving P. Church. New York: Wiley. 1902. $1.50.

TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. XV DECEMBER, 1902 No. 4

LONG-DISTANCE ELECTRIC RAILROADING.

BY LOUIS DUNCAN, PH.D.

Read October 9, 1902.

THE problem of substituting electricity for steam on the trunk lines of the country is of such present importance, the efforts being made to solve the problem are so serious, the difficulties are so great, and the results so meagre, that a general review of the subject cannot be without interest.

The applications of electricity to traction, which I will discuss this evening, may be included under three heads:

1st, — Tramways;

2nd, — Suburban and interurban roads;

3rd, — The field at present occupied by steam locomotives.

In the first two of these applications, the problems presented are practically the same, although the scale of operation is varied. In either case, it is required to operate a considerable number of single cars, or single motor cars and trailers, at frequent intervals. In the third application, however — *i.e.*, in the field now occupied by steam locomotives — the problem is entirely different. Here the necessities of through passenger traffic and of cheap freight transportation demand a few very heavy trains, and the system must be

based on the economical solution of this problem. For tramways and interurban roads a practical and satisfactory solution has been found, although it is possible that more satisfactory methods may be developed. For existing steam roads there is at the present moment no electrical solution which has proved its adaptability.

A very brief history of the development of electric traction up to the present time will be instructive.

Prior to January, 1888, although experimental roads had been built and were in operation in England, Germany, and the United States, yet they were not on a commercial basis, and did not offer any advantages over the then existing traction methods. At that time a road was opened in Richmond, by the Sprague Electric Railway & Motor Company, which in all essential particulars embodied the methods now used.

Mr. Frank J. Sprague graduated from the Naval Academy in 1878. While there he paid especial attention to electricity. I remember him distinctly, as Captain of my gun crew at the school. For not reporting me as often as he might, he earned an esteem which twenty-four years of close association has failed to weaken. After graduation, Mr. Sprague spent six or seven years in the service. He was ordered to special duty at the Paris Exposition of 1881, and had a tour of duty at the Torpedo School at Newport. He resigned in 1885, and with Mr. E. H. Johnson, then President of the Edison Company, formed the Sprague Electric Railway & Motor Company, the object being to develop the application of motors, more especially for traction work. An experimental car was equipped and operated on a small spur of the elevated road. In the latter part of 1886, a contract was hastily closed for the equipment of the Richmond roads, and preliminary work was begun at once; but when the actual condition of affairs was investigated, it was found to be a much more difficult problem than was at first supposed

The railroad company had stated that the maximum grade was from 6 to 7 per cent.; in reality, there were grades as high as 10½ per cent. The tracks were badly laid in streets that were unpaved and muddy, and there were a great many curves of a very short radius. However, the work was pushed forward, and the road was formally opened in January, 1888. As I have said, all the important features of modern electric cars were contained at one time or another in this first road. Series motors were used, with a voltage of approxi-

mately 500 volts at the motor terminals. A successful under-running trolley was developed, a series-parallel control was at first used, and then for reasons which at the time were good, was discarded. A single reduction gearing was at first employed, but afterwards changed to double reduction gearing. The only important feature that did not appear at one time or another in these motors was the use of the carbon brush, which is essential to the successful operation of continuous current railroad motors; this was experimented on, but was discarded, because of the indifferent quality of the carbon used.

On the day that the road was opened, there had been a heavy frost, and mud from the streets had accumulated on the tracks and frozen, the consequence being that there was no ground circuit at times. When the current was made by getting out and pushing the cars until they struck a clean rail, the inexperienced motormen as a rule had the controllers full on, and a number of motors were burned out. The brushes consisted of pieces of brass, set very much as the carbon brushes are now set; the average life of the commutator was not more than two weeks. On the first day, twenty equipments were burned out. For some months the operation of the Richmond road was attended with great difficulties. The motors were not heavy enough for the work; the brushes gave an immense amount of trouble, and the roadbed itself was not fit for heavy traffic. These difficulties were gradually eliminated, and the new roads contracted for took advantage of the experience gained.

The development from the early Richmond experience has been in the direction of making heavier and better motors, of using carbon brushes, and a series-parallel control. The essential parts of the system are, however, adhered to.

As the economy and capacity of electric equipments increased, the city roads were pushed further into the suburbs, and finally roads were built from cities to outlying towns and between cities. This movement is now probably at its maximum; a great number of interurban and suburban roads have been built and more are under construction. The interurban railroad system is simply an extension of the city tramways. The same system is used with the few modifications necessary for the much heavier cars and the much higher speeds required outside the limits of towns.

On some of the interurban roads very handsome and heavy cars are used, fitted out very much as steam cars are, and approximately

of the same size, with speeds up to as much as 60 miles per hour. In fact one road is building special cars which will attain a maximum speed of 75 miles per hour, and make a schedule speed of 60 miles an hour.

When electric roads operated within a short radius, it was the custom to have a central station where the voltage was approximately that intended for use on the cars, and to distribute directly from feed wires connected at the station and to the trolley wire. When the distances became greater, a number of stations employed "boosters" for the outlying districts, the voltage being raised at the station to such an amount that the loss of potential in the feeders would be neutralized, the voltage in the outlying districts being the same as the voltage in the station. When the radius became still greater, as in the case of interurban roads, neither of these systems were applicable, and it is the custom now to distribute, when the distances are considerable, by a high potential alternating current, which, at certain points along the line, is reduced in voltage and changed to continuous current by means of rotary converters. This continuous current has a voltage of from 500 to 600 volts, and the operation from such a sub-station is similar to the operation from an ordinary central station. The advantage of this system is that it allows a very considerable length of line to be operated from a single station, thus giving economy in the generation of power, while it does not interfere with the direct current system of operation on the cars. The disadvantages are in the cost, the losses, and the attendance in the sub-station. If the service is frequent, the average load on the sub-stations will be fairly constant, but where the service is infrequent, then the load factor of these stations is very low. This has in a great many cases been remedied by putting storage batteries in the sub-stations and running the rotary converters at a constant load, the fluctuations being taken up by the storage battery.

It should be specially noticed in this connection that it is of extreme importance that the load on all parts of the system should be kept as nearly constant as possible; if the load on the central station fluctuates, the capacity of the station must be great enough to take the maximum load; this increases its cost and decreases the economy of operation. In the sub-station the same thing holds true, and it is also true of the feed wires. As the loss in the feeders

changes with the square of the current, it will take approximately twice as much copper for the same loss with a 50% load factor, that is where the average power is 50% of the maximum, as it would if the load factor were unity.

The system sketched above is, then, applicable to the first two classes of traction considered, and it is applicable because they embody a frequent service with small units.

When we consider steam railroad traffic, however, we meet an entirely new set of conditions. For through passenger service, a single car, or even two cars, are not enough to give the comfort to which the traveling public is accustomed. This requires heavy trains consisting of a number of cars. Even for a certain class of suburban traffic, where a large amount of travel is concentrated at certain hours, heavy trains must be used, and a large amount of power utilized for each train.

As far as freight is concerned, the great development in railroads in the past twenty years has been in the direction of increasing the size and capacity of the cars and the weight of the train. For freight, especially bulk freight, the minimum of cost is attained with the maximum weight of train.

The annual reports of the more important roads show clearly the tendency to heavier cars and trains for freight. The average train load on the Pennsylvania Railroad has increased in twenty years by about 75% and the capacity of the cars is over 100% greater.

Under these conditions, 500 to 600 volts continuous current motors, receiving current either directly from a central station or from sub-stations, are not applicable. The possibilities of congestion of traffic, especially of freight congestion, make the capacity of sub-stations enormous as compared with the average power required on the line, and there is required in addition an immense amount of copper for the feeders.

Another difficulty is in the large amount of switching to be done, much of it of a complicated nature. If electricity is to be used in terminals and freight yards, a locomotive must be designed which is economical at all speeds and which is under perfect control, and current must be supplied to these locomotives by some means which will not endanger the lives of the train hands. Railroading is dangerous enough as it is, and any additional source of danger must be avoided.

To obviate these difficulties, several plans have been proposed.

The first is to use alternating current motors on an electric locomotive, the locomotive to be supplied with high potential currents directly from the generating station, these currents to be applied at once on the motors or to be reduced by transformers carried on the locomotive. A modification of this is to generate a very high potential at the station and to reduce it to a lower potential by means of static transformers along the line, and to use this lower potential on the locomotive. These plans obviate the difficulty of the rotary transformers that would be needed for changing an alternating to a continuous current, and are cheaper in this way. The alternating current motors also allow higher potentials to be used on the motors, so that it would be possible, for instance, to generate at the station 20,000 volts and transform along the line to 3,000, and apply the 3,000 volts to the motors.

To apply this system practically, there have been a number of experiments made, and some roads are operated on this basis. One method that has been used — the only alternating method now in commercial operation — is to supply three-phase currents either directly to the motor or to reducing transformers which are connected to the trolley wires and are carried on the car. As a rule, this system is installed by using two trolley wires above each track, the rails being taken as a return. A number of small mountain roads in Switzerland and one road in Italy are operated on this basis. I will refer to them later.

Another method that has been proposed several times and is being experimented on by the Oerlikon Works in Switzerland, is to use a single phase alternating current motor on the locomotive, connected to a continuous current dynamo, the current from the dynamo to be used to run continuous current motors on the axles. The regulation of the locomotive is obtained by varying the strength of the field of the continuous dynamo.

Still another method, proposed by Mr. Arnold, is to use a single phase alternating motor, which, when working at normal power, will run the train, when running below normal power will store up air in a receiver, and when more than normal power is required, both motor and compressed air are used.

A further plan just proposed by the Westinghouse Company, and which is being installed on a road between Baltimore and Washington, is, in many ways, the simplest of all. It is well known that a series motor will run on an alternating current circuit, the alterna-

tions in the field and armature occurring together, the effect being, under certain circumstances, much like that of continuous current. The Westinghouse Company proposes to take a motor like an ordinary street car motor, to laminate the entire magnetic circuit, so that there will be little waste due to the alternations of the field, and to supply this with alternating current of $16\frac{2}{3}$ periods. The characteristics of such a machine are very similar to those of the present continuous current type of series motors, while its regulation is easily effected without breaking the circuit by introducing a variable E.M.F. either working with or against the impressed E.M.F. This variable E.M.F. depends on the position of the armature of an auxiliary transformer in the circuit.

To take these methods up in more detail — the three-phase system has been, as a rule, advocated by European engineers. At first glance it presents a number of advantages over continuous current systems, and it has been practically operated in Switzerland. It has not met with any favor in this country, and its achievements on the other side have not been such as to inspire any great hope of its ultimate success. The roads in Switzerland show practically nothing except that a three-phase alternating motor can drive a car — a thing which was very well known before. There is no railroad problem involved in their operation. The cars are small, and the voltages used are in no case above 750 volts — the limit imposed by the Swiss government. The most ambitious three-phase road is one in Italy, running from a point a few miles out of Milan, called Lecco — a total distance of 60 miles. A particular interest attaches to this because the system is that of the Ganz Company, which was strongly recommended by English engineers for the Yerkes tunnels in London. The position of the English engineers in this matter was warmly opposed by Mr. Yerkes and some American engineers, and an ordinary system, very similar to that used on the elevated roads in Boston, New York, and Chicago, was adopted. It seems that very few experiments had been tried on the Ganz three-phase system before this discussion came up, and the road in Italy embodies most of the features that were to appear in the London project. The Lecco road was to have started a year ago the first of September. I was on the road the first of this September, and it was not then in commercial operation; an experimental car made trips over a part of it. Roughly, the system is this: Power is generated at a waterfall in about the middle of the line, and is distrib-

uted at 20,000 volts to sub-stations where it is reduced to 3,000 volts by static transformers. The overhead system consists of two wires over each track, the tracks acting as a return for the third leg of the circuit. The current is collected by a trolley consisting of two metallic rollers about two feet long, mounted on a wooden axle. The rollers are separated from each other by about six inches of treated wood. The roller is held against the trolley wires by compressed air. There are four motors on a car — two of them for permanent use; the other two are merely used in starting. In starting, the fields of the secondary motors are put in series with the armatures of the permanent motors, and a water resistance is put in the armature of the secondary motors. This water resistance is quite ingenious, and will possibly some day work very well, although they have had a great deal of trouble with it up to the present. The plates through which the current passes are stationary; the liquid is forced by compressed air into the tank which contains the plates, and the resistance decreases as the immersed surface increases. When a certain train velocity is reached — which is approximately at half the full speed of the car — and the entire resistance is cut out, the circuits are broken, the secondary motors are cut out, and the permanent motors are put across the supply circuit, with the water resistance in the circuit of the permanent armatures. Then this resistance is gradually cut out as before.

I have not time to go into the difficulties that the Ganz Company has had with this road, but that they are serious is shown by the fact that they are over a year behind the proposed date of opening. The service required is not the heavy service that we need in our railroads, and if it was, the great uncertainty of operation that has been shown would make the system impossible of operation. A great difficulty — in fact, almost a fatal difficulty — with such a scheme is in the liability of trouble with overhead wires. A two-track system, with four wires overhead, these wires having a great difference of potential between them, is almost certain to cause trouble even on a straight track, and where there is switching, the complication becomes enormous.

There is another difficulty of a more technical nature, which depends on the unbalancing of the circuit due to the rail return. I will not discuss this any more than to state that it decreases the normal capacity of the motors — *i.e.*, for a given output they heat more than they should.

It is interesting to note that very close to this road, running about eighty miles out of Milan, is a road equipped by the General Electric Company. The railroad problem is the same in both cases. The General Electric Company finished their road over a year ago, before the time it was promised, and it has been operating successfully ever since, in fact its service goes beyond the guarantees that were given.

Taking up the system of the Oerlikon Company, it has some advantages in that it requires but little trolley wire over the track, and affords an excellent means of regulating the motors. Its disadvantages lie in the fact that it interposes between the trolley and the motors a transforming station which is not only expensive, but adds greatly to the complexity of the system. For heavy railroad work, between this and the three-phase system, I would unquestionably choose the Oerlikon method. Mr. Arnold's proposition has yet to be tried. It affords an ingenious, if doubtful, solution of the railroad problem, but I am very much afraid that its complexity will prevent its adoption. Without going into any particular reason why, it does not sound like an operative system. The Westinghouse system promises much in the way of simplicity and applicability to the heavy problems of steam railroad traffic. A series motor has the advantage that it is to a certain extent self-regulating. If a great torque is required, the armature slows down, the field is strengthened and the maximum effect is obtained. The details of the apparatus have not yet been given out by the Westinghouse Company, but the fact that they have experimented for some time past in their own yards, and have closed a contract for an equipment, shows that they thoroughly believe in its success. One disadvantage is in the low period, which will require large static transformers; but if this is the only difficulty, we can afford to overlook it.

To sum up; as far as the substituting of electricity on steam roads goes, our present methods of electrical traction are not applicable. No method has yet been in successfully practical operation that solves the problem, but our most brilliant experts, having already solved the problem presented by tramway and interurban traction, are seriously attacking the field. The steam railroad companies are becoming interested in the matter, and are lending their coöperation, and we may expect the same results that have been obtained in the past, *i.e.*, that the problem will be solved, and satisfactorily solved.

CONTRIBUTION FROM THE LABORATORY OF ORGANIC CHEMISTRY.

THE DECOMPOSITION OF DIAZONIUM SALTS WITH PHENOLS.

BY JAMES F. NORRIS, B. G. MACINTIRE AND W. M. CORSE.

Received October 27, 1902.

SOME time ago Hirsch[1] undertook a careful study of the preparation of phenol from aniline by means of the diazo reaction, on account of the fact that the yield of phenol was much less than that required theoretically by the equation usually written to express the decomposition of a diazonium salt with water. It was found that a number of reactions take place simultaneously. Among the products of the decomposition was *p*-oxydiphenyl. This compound was shown to be the product of the action of the diazonium salt on a part of the phenol produced in the decomposition. As a result of the study of this reaction, Hirsch showed that when a cold aqueous solution of a diazonium salt was treated with a large quantity of phenol, the diazo compound was extracted from the water. The phenol solution was stable in the cold, but decomposed when heated with the evolution of nitrogen and the formation of oxydiphenyl, phenyl ether, and ill-defined products which were not isolated. Hirsch endeavored without success to extract the diazonium salts from an aqueous solution by substances other than phenol. This method of preparing diphenyl derivatives was, therefore, limited to the decomposition of various diazo compounds with this one substance. The method was not a very satisfactory one, in that large quantities of phenol were used in the extractions, and a number of fractional distillations were involved.

In studying the preparation of phenol from aniline in this laboratory we were led to the view that when a diazonium salt decomposes in the presence of water and a phenol, it reacts to a much larger

[1] Ber. d. Chem. Ges. 23, 3705.

extent with the phenol than with the water. It seemed possible, therefore, that the preparation of diphenyl derivatives by this reaction might be carried out in aqueous solution, and that the method might be developed into a general one for the preparation of hydroxyl derivatives of diphenyl by using, instead of phenol, other compounds of the same class. To test this view, experiments were carried out with benzene-diazonium salts and phenol, pyrocatechin, resorcin, and hydroquinone. It was found that the phenols entered into the reaction when the decomposition of the diazonium compound took place at 75° to 100°, and that good yields of diphenyl derivatives were obtained.

In carrying out the reaction, the phenol, mixed with a small quantity of water and heated to about 90°, was treated cautiously with a cold aqueous solution of the diazonium salt. A vigorous reaction took place, nitrogen was evolved, and a dark, heavy oil separated. When phenol was used, the reaction-product was found to consist of *p*-oxydiphenyl, *o*-oxydiphenyl, phenyl ether, and a tarry mass which could not be purified in any way. The amount of oxydiphenyl obtained was equal to about one-half the weight of aniline used. The reaction furnishes, therefore, a good method for the preparation of this compound. The diphenyl compounds were separated from the reaction-mixture by distillation with superheated steam. This method appears to be much more expeditious than fractional distillation which has been used in the past.

The experiments show that by means of benzene-diazonium salts, a phenyl group can be introduced readily into a benzene ring which contains an hydroxyl group. As usual, the hydroxyl group sends the entering radical to the para position. In the case of phenol, about 90 per cent. of the oxydiphenyl obtained was the para compound. About 10 per cent. of an isomer was obtained which in all probability was the ortho compound. The substance was not obtained in quantity sufficient to make it possible to determine its structure. In the reaction, the hydrogen atom of the hydroxyl group is, to some extent, replaced by phenyl and an ether results.

The decomposition of benzene-diazonium chloride with pyrocatechin proceeded in the same general way. The chief reaction product was a dioxydiphenyl. The substance formed in the next largest amount was shown to be *o*-oxyphenyl ether, which was formed by the replacement of a hydrogen atom of one of the hydroxyl groups by phenyl. A

very small quantity of a substance, which was evidently an isomer of the dioxydiphenyl obtained, was also isolated.

In resorcin there is one position in the benzene ring which is para to one hydroxyl group and ortho to the other. As the orienting influence of both groups is thus, at the same time, directed to this place and the chances for the formation of isomeric compounds accordingly reduced, it seemed probable that the reaction would be a smooth one. The results of the experiments were surprising, therefore, when no diphenyl derivatives could be isolated. The only product which was found was the azo compound, notwithstanding the fact that the reaction was carried out at 100°.

Preliminary experiments only have been carried out with hydroquinone. These indicate that the reaction proceeds in a manner analogous to that with pyrocatechin. The chief product of the reaction in this case appears to be *p*-oxyphenyl ether and not a diphenyl derivative, however. This difference is due, no doubt, to the fact that there is no vacant position para to an hydroxyl group, and as a consequence, the hydroxyl hydrogen is replaced to a larger extent than is the case with pyrocatechin. To some extent, however, a phenyl group is introduced into the ring and a dioxydiphenyl is formed.

The introduction of a phenyl group into the ring in pyrocatechin and hydroquinone modifies the properties of these compounds. The resulting substances show the reactions of the simpler benzene derivatives, but their reactivity is greatly increased. For example, the phenyl derivative of hydroquinone is oxidized by atmospheric oxygen to a dark blue compound, which can be reduced by sulphur dioxide to a colorless substance.

The ethers produced in the reaction are stable, and do not reduce an ammoniacal solution of silver nitrate.

The number of hydroxyl groups in the compounds was determined by preparing the acetyl derivatives. In some cases the methyl ethers also were made.

The descriptions of the compounds prepared from hydroquinone will be given in a subsequent paper.

Experimental.

Decomposition of Benzene-Diazonium Sulphate with Phenol.— The decomposition of benzene-diazonium sulphate with phenol was car-

ried out under a variety of conditions. The method finally adopted was as follows: The diazo compound was prepared by treating a cold solution of aniline sulphate, made by dissolving 40 grams of aniline in a mixture of 80 grams of sulphuric acid and 40 c.c. of water, with a solution of 36 grams of sodium nitrate in 80 c.c. of water. The cold solution was then poured in small portions, with constant shaking, into a large flask containing 80 grams of phenol, which was heated on a boiling water-bath. During the reaction a heavy black oil separated and much nitrogen was evolved. In order to separate the products of the reaction, the mixture was distilled with steam and the distillate was collected in fractions. In the first experiment ordinary steam was used and fourteen fractions of 100 c.c. each were collected. The first nine fractions were found to contain the excess of phenol: in fractions 10 to 14 there were a few needle-shaped crystals, which melted at 67.5° and proved to be *o*-oxydiphenyl. As the major part of the reaction-product was only slightly volatile with ordinary steam, the product of a second decomposition was distilled with superheated steam. The oil formed in the reaction was separated and put into a 500 c.c. flask, which was heated to 150° in an oil bath. The steam, after passing through a three-eighths inch iron pipe heated in a thirty-inch combustion furnace, was at a temperature of 140° to 160° when it entered the flask. Under these conditions all the oxidiphenyl had distilled over when 700 c.c. of water had been collected. The distillate was collected in fractions of 50 c.c. each. Numbers 1 to 5 contained an oil, 6 to 7 a semi-pasty mass, and 8 to 14 a white solid. The oil contained the excess of phenol and some *o*-oxydiphenyl, fractions 6 to 7 consisted of a mixture of the ortho and para compounds, and the white solid was almost pure *p*-oxydiphenyl.

The phenol recovered from the first fractions of the distillate weighed 44 grams. Thirty-six grams had, therefore, entered into reaction with the diazo compound, whereas the theoretical quantity required by the following equation for the aniline used is 40 grams.

$$C_6H_5.N_2SO_4H + C_6H_5OH = C_6H_5.C_6H_4OH + H_2SO_4 + N_2.$$

The separation of the isomeric oxydiphenyls was best effected by crystallization from hot petroleum ether (b. p. 50°-80°) in which the para compound is only slightly soluble in the cold, and in which the ortho compound is much more soluble both hot and cold. *p*-Oxydiphenyl crystallizes well from hot 20-per cent. alcohol.

As a result of the decomposition, there was obtained from 40 grams of aniline 20 grams of pure *p*-oxydiphenyl and 1.5 grams of the isomer. There was a large amount of the reaction-product which was not volatile with steam. It consisted of a black brittle mass, which dissolved in sodium hydroxide and was precipitated from this solution by the addition of hydrochloric acid. The mixture probably contained substances which were formed by the introduction of more than one phenyl group into the benzene ring.

Hirsch noted that an isomer of *p*-oxydiphenyl is formed in the decomposition of benzene diazonium salts with phenol, and assigned to it the ortho structure. No analyses are reported and the properties of the compound are not given. The amount of material obtained by us was not sufficient to warrant an investigation of the structure of the compound. It is, in all probability, an ortho substitution-product produced as a result of the well known orienting influence of the hydroxyl group. An analysis of the compound melting at 67.50 resulted as follows:

0.1308 gram of the substance gave 0.4047 gram CO_2 and 0.0700 gram H_2O.

	Calculated for $C_{12}H_{10}O$	Found
C	84.71	84.31
H	5.88	5.91

The compound crystallizes in colorless needles, which are stouter than those of the para compound.

Decomposition of Benzene-Diazonium Chloride with Pyrocatechin. —As a result of a preliminary experiment it was found that the chief products of the reaction between benzene-diazonium salts and pyrocatechin were dioxydiphenyl, *o*-oxydiphenyl ether, and an oil which could not be distilled without decomposition. Of a number of methods of separating the mixture into its constituents which were studied, the one described below was found to be the best.

The diazo compound was prepared by treating a mixture of 40 grams of aniline in 100 grams of concentrated hydrochloric acid diluted with 100 c.c. of water, with 32 grams of sodium nitrate dissolved in 80 c.c. of water. This solution was poured very slowly into a mixture of 50 grams of pyrocatechin and 50 c.c. of water, which was heated at about 75°. The product was distilled with steam and the distillate collected in fractions. The first fractions,

which contained an oil, were extracted with ether, from which 6.5 grams of phenol were obtained. The solid volatile with steam was found to be *o*-oxydiphenyl ether. About 4 liters of water were necessary to carry over the phenol and the 4.6 grams of the ether formed in the reaction. The solution in the flask was decanted from the non-volatile oil and evaporated to a small bulk. The dioxydiphenyl which separated was filtered off, and from the filtrate 21 grams of pyrocatechin were recovered. Thirty-nine grams had, therefore, entered into reaction instead of 47 grams — the theoretical quantity for a reaction between an equal number of molecules of the diazo compound and the phenol.

The non-volatile oil was extracted three times with boiling water. In all, 2.5 liters were required to dissolve the dioxydiphenyl. On cooling, 5 grams of the compound crystallized out, and 4 grams in addition were obtained on evaporation. The oil insoluble in water weighed 10 grams. It dissolved in alkali, however, and was, no doubt, a mixture of complex phenols formed hy the introduction of more than one phenyl group into the pyrocatechin molecule. An attempt was made to distill this oil. After about one gram of a colorless substance had distilled over at 220° to 250°, total decomposition took place. This distillate, after crystallization from a mixture of toluene and petroleum ether, melted at 147.5° to 148.5°. The substance reduced silver nitrate, gave a white precipitate with lead acetate, and produced a light green color with ferric chloride, which changed to a reddish brown on standing, and to a deep violet on the addition of sodium carbonate. The compound was evidently a pyrocatechin derivative and probably an isomer of the dioxydiphenyl formed as the chief product of the reaction.

The reaction between benzene-diazonium salts and pyrocatechin was brought about in a number of ways, in order to determine the effect of the conditions on the yield of the various products of the reaction. The decomposition was effected by raising gradually the temperature of a mixture of the diazo compound and the phenol, by bringing about the reaction at different temperatures, and at 75° and at 100° in the presence of copper powder. In no case were the yields as good as in the experiment described above.

o-Oxydiphenyl Ether. — About 4.6 grams of this substance were obtained from 40 grams of aniline. The compound crystallizes from dilute alcohol in flat needles, and from petroleum ether in well-formed

six-sided needles terminated by domes. It is slightly soluble in hot water, from which it separates on cooling in long needles. A cold saturated aqueous solution contains .11 gram to the liter. *o*-Oxydiphenyl ether melts at 105° to 106° and has an aromatic odor. It is very soluble in carbon bisulphide, benzene, and glacial acetic acid, less soluble in toluene, and only slightly soluble in petroleum ether. It gives no color with ferric chloride and shows none of the characteristic reactions of pyrocatechin. The results of an analysis follow:—

0.1105 gram substance gave 0.3125 gram CO_2 and 0.0553 gram H_2O

	Calculated for $C_{12}H_{10}O_2$	Found
C	77.42	77.08
H	5.37	5.56

A molecular weight determination, using alcohol as the solvent, gave 176 as the result instead of 186, the theoretical number.

The acetyl derivative was made by heating the phenol with an excess of acetyl chloride. After the product so obtained had been treated with sodium hydroxide, it distilled without decomposition at 358° to 360° (uncorrected). The compound is a thick oil, which dissolves in the usual organic solvents. An analysis gave the following results:—

0.1251 gram substance gave 0.3386 gram CO_2 and 0.0607 gram H_2O.

	Calculated for $C_{14}H_{12}O_3$	Found
C	73.68	73.82
H	5.26	5.39

The methyl ether of *o*-oxydiphenyl ether was prepared by heating a solution of the phenol in methyl alcohol with the calculated quantities of potassium hydroxide and methyl iodide. The compound crystallizes from methyl alcohol in long, flat, six-sided crystals. It dissolves in the ordinary solvents and melts at 77°. The formation of this compound and of the mono-acetyl derivative described above shows that the structure assigned to the *o*-oxydiphenyl ether is correct. An analysis of the methyl ether gave the following results:—

0.1074 gram substance gave 0.3063 gram CO_2 and 0.0589 gram H_2O.

	Calculated for $C_{13}H_{12}O_2$	Found
C	78.00	77.78
H	6.00	6.09

Dioxydiphenyl.—Nine grams of this compound were obtained from 40 grams of aniline. The crude substance which was separated from the original reaction-product by extraction with water, was dark brown in color and somewhat gummy. In this condition it is best purified by crystallization from hot petroleum ether, in which it is only slightly soluble. It melts at 136° to 136.5° and boils above 360° without decomposition. It is very soluble in alcohol, chloroform, and ether, less soluble in carbon bisulphide, petroleum ether, and hot water. A cold saturated aqueous solution contains 1.6 grams per liter. The compound gave a light green color with ferric chloride, which changed to a reddish brown on standing, and which was changed to a deep violet on the addition of sodium carbonate. It reduces silver nitrate and gives a precipitate with lead nitrate and with bromine water. No marked coloration is produced when the substance is heated with phthalic anhydride and sulphuric acid. An analysis gave the following results:—

0.2048 gram substance gave 0.5826 gram CO_2 and 0.1022 gram H_2O.

	Calculated for $C_{12}H_{10}O_2$	Found
C	77.42	77.53
H	5.37	5.54

The diacetyl derivative was obtained by heating the phenol with an excess of acetyl chloride. It crystallizes from alcohol in long six-sided crystals, which melt at 77° to 77.5°. The analytical results were as follows:—

0.1285 gram substance gave 0.3341 gram CO_2 and 0.0628 gram H_2O.

	Calculated for $C_{16}H_{14}O_4$	Found
C	71.11	70.91
H	5.18	5.43

Two dioxydiphenyls are possible as the result of the introduction of a phenyl group into the benzene ring of pyrocatechin. In one compound the group introduced is ortho and meta to the two hydroxyl groups: in the other it is para and meta to these groups. An attempt was made to determine which of these structures belonged to the dioxydiphenyl formed as the chief product of the decomposition of the diazonium salt with pyrocatechin. The phenol was converted into the corresponding dimethyl ether, which was then oxidized. It was expected that in this way the phenyl group would be converted into carboxyl and, as a result, a dimethoxy-benzoic acid obtained. If the phenyl group occupied the position para to one of the hydroxyl groups, the oxidation-product would be veratric acid, a well described compound. The oxidation was brought about under a variety of conditions with chromic acid and with potassium permanganate. Only when the last-named substance was used could any oxidation-product be isolated, which in this case proved to be benzoic acid. The structure of the compound was not established, therefore, but on account of the usual directing influence of the hydroxyl group and the results with phenol, it is highly probable that the substance is 3, 4-dioxydiphenyl.

Boston, October 27, 1902.

ANTISEPTICS, AND THEIR USE IN THE PRESERVATION OF FOOD.[1]

By SAMUEL C. PRESCOTT.

If we compare the processes of food preservation in use today with those commonly practiced thirty or forty years ago, we shall find not merely a considerable increase in the number of methods, but also an immense development in the application of the older methods. While as a whole the development of these methods has been of great benefit to mankind, it has also given rise to some of the most perplexing and difficult questions which have ever been put to the sanitarian or hygienist, and one of these concerns the use of antiseptics. This particular subject has been for a long time a source of much contention, and its satisfactory solution is far from having been reached. It may be of interest, however, to inquire briefly into the present status of the question and its bearing upon the subject of food preservation. In order to view the matter in its proper perspective some general statements as to the methods and aims of food preservation may be timely. It may be well to state at the outset that the general aim in all these processes is the same, namely, to prevent putrefactive or fermentative changes, and thus to make the surplus food of one place or one time available in another place or at another time.

Fermentation, Putrefaction, and Decay. — Unless some means are taken to interfere, nearly all foods are likely to undergo important changes caused by the action of extremely minute living organisms, variously known as germs, bacteria, microbes, bacilli, etc., or by the so-called unorganized ferments. The chemical changes thus brought about by the activity of micro-organisms we sometimes designate as fermentation processes, although it is more convenient in general to subdivide them into the two classes, fermentations and putrefactions. By fermentations we mean changes taking place spontaneously in

[1] Read before the joint meeting of Atlantic States Canned Goods Association and Western Canned Goods Association, at Milwaukee, February, 1902.

sugary or starchy foods, the microbes transforming these substances into acids for the most part, and thus giving rise to "souring," as in sour corn and sour peas. Putrefactions, on the other hand, are the changes which are brought about by the bacteria in the more complex proteid or albuminoid foods, such as meats, which are rich in nitrogen. Here, instead of the formation of acids, there may be a great variety of products, including malodorous gases, and other bad smelling compounds, and sometimes poisonous bodies, the so-called ptomaines, which if taken in with the food give rise to sickness and symptoms of poisoning. The bacteria causing putrefaction live anaërobically, *i.e.*, they do not require free contact with the air. "Decay" is a term sometimes used in a broad way to describe any of these processes, and sometimes used in a more specific way to indicate the changes taking place in albuminous matters in contact with the air, in which case no bad smelling compounds are formed unless putrefactive processes are going on within the food at the same time.

Methods of Food Conservation. — Of the processes which may be employed in food conservation, we may easily distinguish four principal kinds:

1. Cold Storage.
2. Preserving, pickling, and drying.
3. Canning.
4. The use of antiseptics.

The desired result may be obtained by the use of a single one of these methods, the choice depending upon the character of the food to be preserved, or they may be used in combination, in which case the fourth method is generally combined with one of the others. Let us now briefly consider these four methods, and determine the underlying principle in each.

Cold Storage. — It is a well-known fact that almost all kinds of food "keep" better in the cold than in warmth, and it has become a general practice to use ice in the preservation of our daily foods. In addition to its convenience and general usefulness, there is a sound scientific principle underlying this practice, for we find that the micro-organisms of fermentation and putrefaction are so much weakened or so stiffened by cold as to be rendered inert, and therefore, for the time being, absolutely harmless. Obviously, this method can be employed only when it is desired to conserve materials for comparatively short periods of time, although with proper refrigerating appliances

some classes of food stuffs might be kept forever. This method is of inestimable value, for by it we are able to keep many foods fresh almost indefinitely, and may even transport fresh foods over long distances. It should always be borne in mind, however, that refrigeration is not sterilization, and when foods taken from cold storage are warmed, the processes of decomposition proceed as vigorously as ever. Consequently, foods should always be consumed or cooked immediately after leaving the cold chambers. This method is a process of prevention of the growth and activity of microbes, not of sterilization.

Preserving, Pickling, and Drying. — These processes are analogous in a general way to the preceding, inasmuch as they are not sterilizing processes, but depend for their efficiency upon such modification of the physical properties of the food substance that bacterial growth cannot take place. In order that germs may develop abundantly, a comparatively large amount of water is necessary, and if the percentage of water is diminished, as by drying, the germs are not able to thrive until the conditions again become favorable. In pickling in brine and preserving with sugar, a slightly different action takes place, for here we increase the density of the medium by the addition of these substances which have a strong affinity for water. The concentrated solutions thus formed tend to absorb more water by osmosis, and when microbes come in contact with such substances, the water is extracted from their bodies and they are rendered inert and innocuous. But, as with the cold storage of foods, protection is afforded only temporarily, for if we weaken the strength of the brine or sugar sufficiently, we find that the vitality of the bacteria has been merely diminished, that in reality we have had a case of suspended animation, and that fermentative processes will go on again vigorously.

Canning. — This method of food preservation is of the very highest importance and value. While by the use of the foregoing it has been possible to establish a temporary immunity against the attacks of the fermentation microbes, by hermetically sealing the foods in cans or jars and subjecting them to sufficiently high temperature we may guard permanently against any such invasion. In other words, if we *sterilize* our food materials we have no need to fear decomposition or fermentation, for we have destroyed the cause of such changes. Absolute sterilization means the killing of all bacteria, so that we have here the most nearly ideal of all preservation processes

in actual use, when considered from the fermentation and sanitation expert's point of view. This subject has already been so thoroughly discussed that further comment is unnecessary.

Use of Antiseptics or Preservatives.—We come now to the last of the list of methods mentioned, and the one which must be viewed with the least satisfaction and confidence because of the grave questions as to the effect of the chemical substances used as preservatives upon the health of the consumers.

By a preservative or antiseptic we mean a chemical substance which, owing to its toxic or poisonous action on microörganisms, is capable of retarding or preventing fermentation and putrefaction. If the toxicity is sufficiently great to *kill* the organisms, we speak of the substance as a disinfectant. The distinction between a disinfectant and an antiseptic is, then, a difference in strength and germicidal power, for in very small amounts the strongest poisons act only antiseptically; that is, they do not produce the death of the germs. Preservatives such as are used in food substances are all antiseptic, but it is evident that not all antiseptics can be used as preservatives. The preservatives in common use, although sold under a variety of names, are in reality comparatively few in number as shown by the analyses which have been made from time to time. The most important of these are boric or boracic acid and borax, salicylic acid and sodium salicylate, benzoic acid and sodium benzoate, fluorides, sulphites, and formaldehyde. Borax or boric acid, or mixtures of the two, are extensively employed in the preservation of meats, fish, and dairy products. Salicylic acid and its salts are used for fruits and vegetable products chiefly, such as jams and jellies, and in beverages. Sulphites are used in the same food substances as salicylic acid, and also to some extent for meat. Benzoic acid finds use in beverages, and in fruit and vegetable preparations such as catsups. Formaldehyde is especially used for milk, and fluorides are used in some beverages, especially beer.

From authoritative analyses of 67 preservatives it has been found that 33 contained either borax or boric acid as the most active constituent, 10 contained sulphites; 8, salicylic acid or its sodium salt; and 7, benzoic acid or its sodium compound, while the others were either mixtures of the foregoing or were composed of other substances. Analysis has also revealed the fact that dealers sometimes sell the same compound or mixture under different names and at different

prices, and often these substances are described as perfectly harmless, and at the same time of the highest germicidal efficiency. It may also be of interest to know that all the preservatives commonly used in foods can be easily detected by the skilled chemist, in spite of the statement sometimes made by agents that certain of their wares baffle chemical examination, a statement which amounts to a confession that these are regarded as suspicious.

But of all the questions relating to the use of preservatives, that of the effect of the substances which they contain upon health is of greatest moment, and is likewise the most difficult of solution. Generally speaking, those substances which exert a harmful effect upon bacterial life will produce a similar effect upon higher organisms, although it may be to a much less degree; and this fact forms the basis of nearly all objections to the use of antiseptics. That is, the general effect of such substances on living things is everywhere similar, although differing in intensity. For example, corrosive sublimate is one of the strongest bacterial poisons known, and also one of the poisons most deadly for human beings, and the same rule holds good for most of the substances of very strong antiseptic or disinfectant character. Obviously, nothing should be added to foods which is in itself inimical or poisonous, or which interferes with the normal processes of digestion. And here it should be borne constantly in mind that the old saying, "What is one man's meat is another man's poison," fits the case exactly. It may be possible, perhaps, for strong, healthy individuals in good condition to eat foods containing a small amount of toxic antiseptic without serious consequences. It is entirely another matter, however, when invalids or delicate young children are given such foods, and the result is likely to be far from desirable. Further than this, we do not know with certainty as to the cumulative effect of these substances, that is, whether they are readily taken care of and excreted, or whether they are retained within the body until considerable amounts have accumulated. We do know, however, that in large doses these substances almost invariably act harmfully. On the other hand, it is also possible to conceive that some of these substances are no more harmful than common salt, though this is at least doubtful.

After reviewing many articles written by well known physiologists in Germany, France, England, and America, I have been strongly impressed with the conflicting and inconclusive character of

the evidence. For example, Liebreich declares that boric acid and borax have no harmful effect when consumed in small quantities, while almost at the same time, Halliburton asserts that all preservatives should be forbidden by law. Lebbin and Kallman made experiments on animals to show that sulphites were absolutely harmless and less poisonous than salt, and state that "the toxicity of neutral sulphites is a legend." On the other hand, both Lange and Gruber object to the use of sulphites on sanitary and hygienic grounds. In a similar manner, Tunnicliffe and Rosenheim proved to their own satisfaction that neither boric acid nor formaldehyde exerts a harmful action upon healthy children, while Kister, in a very carefully conducted research, arrives at an opinion diametrically opposed. I could go farther, and cite other examples but without finally settling the question in dispute. Enough has been said, however, to indicate the prevailing difference of opinion. In spite of the large amount of work which has been bestowed upon this subject, the discussion and experimentation have hardly passed beyond the academic or theoretical stage, and there is great need for the more practical demonstration before we accept the use of these substances as harmless. I believe it to be wise to regard every chemical preservative as guilty until proved innocent. A little thought will show how difficult accurate, reliable experimentation must be in this matter, for a living body is a far more variable reagent than a chemical solution and, moreover, different individuals or animals must of necessity react differently according to their state of health, powers of digestion, occupations, and so forth. Thus it will be necessary to make many observations before the matter can be settled.

It is true that there is a class of foods such as ham, bacon, dairy products, jams, etc., of such character that their flavor or usefulness would be destroyed by heat. For these harmless preservatives would be of special value, and use of preservatives in such foods has some slight excuse on the grounds that the antiseptic is necessary to prevent decomposition. In such cases every package should be plainly labelled with the name of antiseptic it contains. In canned goods, on the other hand, the use of any antiseptic should be unhesitatingly condemned, for it is absolutely unnecessary if the food has been properly prepared and sterilized. Addition of any preservative to canned foods is a virtual acknowledgment that the packer does not know his business, and the use of such substances can only be

regarded as a makeshift to cover up slovenly, uncleanly, and inefficient methods. The absence of preservatives in canned goods is an indication of good, intelligent management, cleanly methods, and wholesome food, as a rule. Their presence shows the reverse characteristics, for if a manufacturer depends upon the use of a preservative to ensure the keeping quality of his goods, he is putting a premium upon inefficient and careless work.

Whether preservatives are ultimately proved to be injurious or otherwise, their use in canned goods should never be allowed, for the simple reason that they are unnecessary if the goods have been properly prepared.

In the different states there are numerous laws regulating the use of these chemical antiseptics in foods. As these laws are different, a man might conceivably be acting within his rights in one state and violating the law by selling his product in another. At the present time the only way to be sure of being on the right side is by abstaining entirely from the use of antiseptics, for here as in all things else, total abstinence is the only *absolutely* safe method of keeping out of danger.

It is probable that their use cannot be at present entirely prevented. Consequently a national law regulating the use and restricting abuse of such substances is most to be desired. That this subject is of international or universal interest is made evident by the amount of discussion which has been given to it in England and on the Continent. The latest contribution is in the recently published report of the Committee appointed by the British Government to investigate the use of preservatives and coloring matters in foods. The report of the Committee is, on the whole, unfavorable to the use of preservatives. It recommends that the use of all preparations of formaldehyde, or formalin, in foods or drinks should be absolutely prohibited, and that salicylic acid be not used in greater proportion than one gram per pint in liquid foods or one gram per pound in solid food — its presence in all cases to be declared. The report further recommends that the use of any preservative or coloring matter in milk should constitute an offence; and that for preservation of cream, butter, and margarine only boric acid or mixtures of boric acid and borax should be used. The amount of antiseptics should not exceed 0.25 per cent., expressed as boric acid, in cream, or 0.5 per cent. in butter or margarine. It is interesting to note that the report insists

that no preservative of any kind should be used in any dietetic preparation intended for the use of infants or invalids, and also opposes the use of copper salts in "greening" of vegetables, although one member of the Committee demurred in this judgment. Comment upon this excellent report is almost unnecessary, except to say that it emphasizes anew the unsettled state of the question and the necessity for much further experimentation before anything like a final verdict can be pronounced.

The prohibition of the use of preservatives in foods designed especially for infants and invalids betokens some suspicion on the part of the Committee that there is no chemical antiseptic which is not objectionable under some circumstances.

In conclusion, let me reaffirm the necessity for more information upon this important subject. I believe it would be wise for such bodies as this association to take whatever steps may be within their power towards further investigation, either by agitation for a national court of inquiry similar to that recommended by the English report, or otherwise. The Agricultural Department at Washington has already done much in this direction, but more could be done if the manufacturers of preserved foods would show a spirit of something more than selfish interest, and use their power to further the work. In my opinion, such action on their part would be fully repaid, even in a financial way. And especially let me emphasize again that the two best agents for preservation of foods that are at our disposal are cold and heat; cold for the fresh foods which are to be kept temporarily, and heat for that greater and ever-increasing class of canned foods which can be kept for any length of time and in all climates, and which already play so important a part in the nutrition of the world. If the producers of canned foods are wise, they will endeavor to secure complete sterilization by heat, cleanliness, rapidity and economy of production, and intelligent, scientific management of their factories. They will thus have no use for preservatives, but will regard them as undesirable not only because unnecessary, but also because there is no valid reason for the addition to what must otherwise be regarded as pure foods, of substances of dubious effect upon the health of the consumer.

CORROSION OF THE STEEL FRAMES OF BUILDINGS.

By CHARLES L. NORTON.

THE constantly increasing use of steel as a structural member in modern buildings has led to many questions as to the permanency of the steel as sometimes used for this purpose. The examination of buildings ten to fifteen years old, when, during alterations, the steel framework has been exposed to view, reveals all stages and conditions of disintegration of the steel. So great has been the corrosion, even in this short time, in some cases, that a note of alarm has been sounded by some engineers most familiar with the subject. The use of steel beams and posts is of so recent date that no very exact deduction can be drawn as to the exact time required for a very serious or destructive loss of steel through corrosion; but surely, when a steel plate one-half inch in thickness loses more than one-eighth of an inch in five years, there arises a question as to the ability of the structure to last more than twenty-five years.

Some of the factors in the matter of corrosion of the steel we know; others we do not know, and cannot until after a lapse of some years.

There can be no question that moisture and carbon dioxide are the active agents in causing much of the rusting of the steel. To what an extent the two are relatively responsible and in what measure they need renewal, to keep up the process, is uncertain. It has been held that the formation of a coat of rust upon the surface of steel was the beginning of a progressive action whereby the rust, or iron oxide, acted as a continuous carrier of oxygen to the steel beneath. This process seems to require only moisture and atmospheric air containing carbon dioxide to start it, but as to the depth of penetration of the process I know of no assignable maximum in any given time. It is extremely probable that in a comparatively dry place the process is exceedingly slow.

There can, of course, be no question, in many cases, as to the ease of access to the steel of both moisture and carbon dioxide.

When steel is bedded in the wall of the building, as is almost always the case, the changes in temperature from time to time, as well as the more or less constant difference in temperature between the two faces of the wall, tend to cause a condensation of moisture in the wall at different points. Further, the necessary carbon dioxide is most plentiful in the large cities, where the steel frame is most common.

When the walls of the building are of brick or stone, moisture and carbon dioxide may usually enter at the joints and, to a greater or less extent, through the body of the stone or brick. Few stones are, however, porous to such an extent as to allow an appreciable penetration. Terra-cotta tile is of itself porous, and the existence of air passages tends to increase the condensation of moisture and absorption by the terra-cotta and possible contact with the steel. Concrete, made of Portland cement with sand and either cinders or stone, would seem to offer more protection to the steel than any of the materials just mentioned; yet, we hear from time to time of the loss, by corrosion, of steel bedded in concrete.

A study of the action of Portland cement concrete on steel was begun under my direction by Mr. P. C. Pearson in December, 1901, and it is my purpose to report upon this and some later observations as a preliminary to more work of the same nature now under way.

It has been held by several engineers that the mere alkaline nature of Portland cement was a sufficient guarantee of its protecting steel from rusting. There is, of course, good chemical reasoning for this, the familiar use of strong alkaline solution in boilers to prevent the formation of scale being based upon the same principle. This would seem to settle the matter once and for all, were it not a fact that steel bedded in concrete has corroded very rapidly, while other steel in a different concrete of the same kind of cement stands without change for ten years or more.

The investigation was started, not to find out that steel could not be protected by concrete or that it could be, for on that point we were sure, to start with, but we have tried to find a reason for occasional failure and to suggest a remedy.

An examination of several cases where expanded metal had been embedded in concrete showed plainly that wherever the steel was exposed through cracking, rusting began, even though the cracks were very fine. It would seem that the alkaline nature of the cement would

be sufficient to prevent corrosive action occurring within a few hundredths of an inch on the moist surface of the steel, but such is not always the case.

To study the matter systematically, two brands of American Portland cement (*Alpha* and *Lehigh*) were selected; two kinds of cinders, one from the Sugar Refinery, the other from the Boston and Albany locomotives; a sharp, clean beach sand; and a hard, clean broken stone, the larger part being fragments of flint and trap rock. Concretes were made up in bricks about 3″ x 3″ x 8″, with the steel specimens near the centre.

The following mixtures were tried at first; others will be reported on later: Neat cement; cement, one part, to three of sand; one part of cement and five parts of broken stone; and one part of cement to seven parts of cinders. All briquettes were made in duplicate with both cements. There were later made up briquettes of one part of cement to two parts of sand and five parts of cinders, and of one part cement to two of sand and five of crushed stone. The table below gives a summary of the mixtures: —

Alpha Cement.	Lehigh Cement.	Sand.	Stone.	Cinders.
1	0	0	0	0
0	1	0	0	0
1	0	3	0	0
0	1	3	0	0
1	0	0	5	0
0	1	0	5	0
1	0	2	5	0
0	1	2	5	0
1	0	0	0	7
0	1	0	0	7
1	0	2	0	7
0	1	2	0	7

It was hoped to vary the density, the porosity and the nature of the contact with the steel, as well as the chemical composition of the concretes. The cements were tested chemically and physically and found good. The cinders, when washed down with a hose stream and dried, tested distinctly alkaline, and analysis revealed very small amounts of sulphur. The stone and sand were thoroughly washed and clean. The ingredients were mixed dry in every case and, when wet, thoroughly mixed and tamped until wet on top.

The cleaning of the steel was the most troublesome problem met

with. It was necessary to scour the pieces, then pickle in hot dilute sulphuric acid, and finally dip into hot milk of lime. When cold, the lime was removed with a wire brush. This left the steel clean and bright, ready to be put into the test bricks.

The specimens used were a mild steel rod 6″ long and $\frac{1}{4}$″ in diameter, a piece of soft sheet steel 6″ x 1″ x $\frac{1}{32}$″, and a strip of expanded metal 6″ x 1″, all three pieces being put in each brick. Since time would not permit of our exposing these specimens to natural conditions, we enclosed them in several large tin boxes, sealed tightly,

FIG. 1. — STEEL PROTECTED BY CEMENT.

and subjected one quarter of them to an atmosphere of steam, air and carbon dioxide, and second quarter to air and steam, a third to air and carbon dioxide, and a fourth stood upon the table of the room, with no special care as to their temperature or dryness. Of the entire number, about one-half were set in water for one day, the rest for seven days, before sealing up.

At the end of three weeks the briquettes were carefully cut open and the steel examined and compared with specimens which had lain unprotected in each of the tin boxes.

Those specimens which were mixed of neat cement can be dismissed without discussion, for the protection was perfect. The steel was as bright as when put in. (Figure 1, Nos. 25, 26, 84, 68.)

The unprotected pieces were found to consist of rather more rust than steel. The steel was wrapped about pieces of uralite, to serve as a means of identifying it by number, the stamped numbers being nearly obliterated by the rust.

FIG. 2. — STEEL RUSTED BY CONTACT WITH CINDERS.

Of the remaining specimens, hardly one had escaped serious corrosion. The location of the rust spot was invariably coincident with either a void in the concrete or a badly rusted cinder.

In the more porous mixtures, the steel was spotted with alternate bright and badly rusted areas, each clearly defined. In both the solid and the porous cinder concretes, many rust spots were found, except where the concrete had been mixed very wet, in which case the watery

cement had coated nearly the whole of the steel, like a paint, and protected it.

Some briquettes made later of finely ground cinders and cement, in varying proportions, when exposed to moisture and carbonic acid, showed how effectually the presence of cement prevented rusting, even in a highly porous mass, — one cement to ten of cinder, provided there were no cracks, or crevices, or distinct voids.

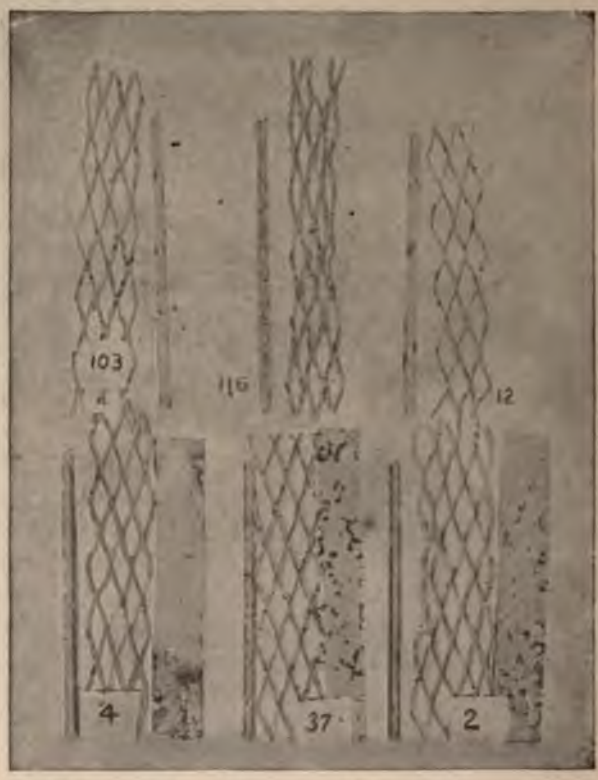

FIG. 3. — STEEL RUSTED AT VOIDS IN CONCRETE.

From the examination of these several hundred briquettes we were able to draw several conclusions: —

First. Neat Portland cement, even in thin layers, is an effective preventive of rusting.

Second. Concretes, to be effective in preventing rust, must be dense and without voids or cracks. They should be mixed quite wet where applied to the metal.

Third. The corrosion found in cinder concrete is mainly due to the iron oxide, or rust, in the cinders and *not* to the sulphur.

Fourth. Cinder concrete, if free from voids and well rammed when wet, is about as effective as stone concrete in protecting steel.

Fifth. It is of the utmost importance that the steel be clean when bedded in concrete. Scraping, pickling, a sand blast and lime should be used, if necessary, to have the metal clean when built into a wall.

FIG. 4.—PAINTED STEEL IN BRICKWORK. FIVE YEARS OLD.

In the matter of paints for steel, there is a wide difference of opinion. I cannot believe that any of the paints of which I have any knowledge can compare with a wash or painting with cement. Moreover, if paint does disintegrate, it leaves a thin void next the steel, the worst possible condition. I examined some steel Z-bars not long ago, which were exposed in process of altering a building five years old. It was clear that the steel was rusty when painted and that moisture had penetrated through the paint, caused the rust to increase

and split off the paint. This was a case where the steel was built into the brickwork with no attempt at any protection other than the paint.

It is, in my opinion, perfectly clear that the coating of all steelwork with cement before applying the concrete or tile or brick, as the case may be, is an absolute essential, if the formation of rust and consequent weakening of the steel is to be prevented. The thickness of the cement layer need not be great, but it should be a continuous coating, without cracks The steel should be perfectly clean; but if, as is often the case, the choice is between paint and rust which accumulates during construction, the paint is to be preferred.

Mr. Pearson suggested the use of Portland cement in protecting the under side of railroad bridges against rust and the blasting action of the gases and cinders from locomotives. I think this merits a careful trial.

It is intended to take up the study of paints as a protection for steel, and to study, as well, the action of corrosion with long lapses of time in the walls and buildings of the Experiment Station now about to be erected. The first fire-testing work will also be upon the tile, brick and concrete protection of steel from fire. Next we propose to study the effectiveness of the many kinds of "finish" for buildings. A small, two-story house of refractory material, into which the finish to be tested can be built, is needed for this work, and already several materials are waiting to be tested. The kiln for testing floor spans, beams, and posts is to be about fifteen by twenty feet, and it will be heated by a battery of oil burners well above the melting-point of cast iron.

ALUM IN WATER.

A. H. Low's Modification of the Logwood Test.

By ELLEN H. RICHARDS.

In Volume 4 (1891, p. 194) of this journal, a method was described for detecting alum in water by the use of a freshly prepared solution of logwood.

With the increasing use of mechanical filters the test has become of an importance little dreamed of at the time. Various workers have spoken for and against the method. Professor J. W. Mallet, of the University of Virginia, suggested in 1899 the use of hæmatoxylin, which now may be had of considerable purity — by which one part of alum in 5,000,000 could be detected.

As early as 1898, Mr. A. H. Low (M. I. T. 1876), of Von Schulz & Low, Denver, Colorado, having occasion to test the effluent from the mechanical filters of the Denver Union Water Company, began experimenting with the logwood test with especial reference to the interfering substances.

At that time one part in 4,000,000 was his claim for the test.

Mr. Low has continued his experiments and has given his permission for the publication of his method, which appears to be a distinct contribution to the accuracy and delicacy of the determination, since one part in 8,000,000 may be detected. The exclusion of carbon dioxide up to a certain stage in the process, when it is required, and the prevention of access of alkali from glass vessels by the use of platinum are essential points.

Mr. Low has kindly supplied the following directions: —

Directions for the Alum Test. — The logwood solution is made as follows: Take two grams of logwood chips and boil one minute in a platinum dish with 50 c.c. of distilled water. Decant the solution and boil again for one minute with 50 c.c. of water. Decant this and similarly boil a third time with 50 c.c. of water. Decant this into a plati-

... three drops for each test. Kept in ... for several days at least.

... Boil 50 c.c. of the water in a platinum ... carbon dioxide. Add three drops of ... continue boiling for a few seconds to develop ... glass flask and cool quickly under the tap ... solution too long in the glass). Transfer ... in carbon dioxide from the breath by ... there is no further decolorization. Pour ... for comparison with standards similarly ... stand several hours before taking the final ... is used at any of the decantations. The ... aluminum sulphate in 8,000,000 parts of water.

... distilled water, if not completely decolorized ... a tint perceptibly fainter than that produced ... of aluminum sulphate.

... that carbon dioxide must be kept absent until ... The solution is therefore transferred to a beaker ... flask free from carbon dioxide for the next test.

... logwood appears to answer.

... good for several days, at least, if kept in plati-

... aluminum instead of glass for boiling the test.

... carbon dioxide instead of acetic acid.

... as pointed out by the late Professor A. R. ... produce a tint almost as strong as if it were in ... removal of the hydrate is a difficult matter.

... method of procedure is as follows: first, test the water ... If no tint, or none exceeding that of the blank, ... several hours, or over night, that is sufficient. ... persists, or a colored precipitate settles out, it is ... if this is due to aluminum hydrate. Pour a ... several times through a double Swedish filter ... filtrate. If the tint produced is weaker than that ... water, repeat the operation on a fresh portion ... the same filter, and continue repeating with new ... and always using the same filter, until it is ap- ... diminution of the tint can be effected. The

tint finally remaining may be assumed to be due to a salt of aluminum in solution.

An alternative method is to clog a filter with a little aluminum hydrate, wash until no test is given, and then filter the sample of water. The writer does not agree with Mr. Low's suggestion to allow the filtered water to stand several hours and then refilter. The filtrate from a mechanical filter which uses alum should be tested at once. A slow decomposition appears to take place by which aluminum hydrate separates out. While it may be said that consumers do not use the water until after the lapse of some hours, the chemist should be able to say whether any undecomposed alum comes through the filter.

Mr. Low gives the following directions for the use of hæmatoxylin:

Dissolve 25 mg. in 25 c.c. of warmed water. Add one drop to 50 c.c. of the water to be tested, boil in a platinum dish until the color appears to be fully developed — about thirty seconds. Pour into a flask, cool under the tap. Blow carbon dioxide from the breath through the solution so long as any color due to alkali seems to be discharged.

SOME NOTES ON SEVERAL TYPES OF MANTLES FOR INCANDESCENT GAS BURNERS.

By WILLIAM LINCOLN SMITH, S.B.

Received November 14, 1902.

Some nine or ten months ago I had occasion to make use of a number of mantles for incandescent gas burners and, as it fitted in with some other work which I had on hand, I made a series of tests upon a number of styles of mantles on the market in Boston with a view to the determination of their characteristics. In addition I made some tests upon a number of tinted chimneys and globes for use with the mantle.

The results which were obtained were partially presented in the spring at one of the local scientific clubs and are embodied rather more fully in the following account of the work, which I may say makes no claim to be exhaustive.

The instruments used were a Weber Portable Photometer, made by Krüss, and a König Spectrophotometer, loaned me by Professor Cross of the Department of Physics (through whose kindness I was further enabled to do a considerable portion of the work in one of the dark rooms of this department of the Institute). The gas supply was taken from the city mains, metered by a 3-light Wet Test Meter, and the pressure was controlled by a regulator kindly loaned me by Dr. Gill of the Chemical Department.

Ten types of mantles were examined, which are numbered consecutively from 1 to 10 in the tables and on the plots. I only give the names of the three types which I finally chose for complete study. These were: 1st, The Yusea. 2d, The Majestic, and 3d, The Admiral. All of the mantles were purchased of retail dealers at various times without any suggestion as to the use to be made of them, and six of each were tested, the results here given being in each case the mean of the six specimens. Very slight changes in position of the mantle on the burner were found to make exceedingly large variations in

the photometer reading, due to the varying amount of net on the rear side of the mantle which showed through the meshes on the side toward the photometer. I found that the individual mantles of a given type were hardly near enough alike to allow of any general method of correcting for this, and accordingly obtained a burner for each type of mantle which could be slipped over the free end of a fixed pipe and brought definitely to a fixed position by cross hairs in a small telescope and a gauge mark on each burner. In order to locate the mantle properly at first, I adjusted the burner for maximum candle-power as shown on the photometer, and then turned the burner on the pipe until the photometer gave the highest possible reading. Then by means of a lens I projected an image of the mantle on a sheet of cardboard, tacked on the wall behind the photometer, and drew out with ink the outline of a large section of the mesh as it appeared in the image. When a second mantle of similar type was to be used, it was placed on the burner and turned so that the image of its mesh coincided as nearly as might be with that lined out upon the cardboard.

With a given type of mantle tests were first made to determine the change in candle-power for different rates of consumption of gas; then the mean of the six sets were determined, and the two mantles which came nearest to this mean were selected for further examination. These two were then compared with the spectrophotometer at fifteen equidistant points from $\lambda = 7750$ to $\lambda = 4250$ inclusive, and if the ratio between the two mantles appeared irregular, another mantle was compared also. Two mantles as nearly similar as might be having been found, they were laid aside for further study.

The Instruments.

Weber Photometer. — This instrument was used with a small incandescent lamp as a secondary standard. It was run from a portable storage battery (kept steadily charged by a battery of gravity cells), and in circuit with it was placed a small finely divided rheostat, so that the voltage applied to the lamp as indicated by a Weston voltmeter could be carefully adjusted and held constant within very narrow limits. This secondary standard had been carefully checked against an amyl-acetate lamp. It was found possible to do all the work required of this instrument, while making use of only two com-

binations of diffusing plates in the photometer box, and keeping the lamp under test at a fixed distance of 730 mm. from the instrument. These two combinations were: for the feebler candle-powers, Plate 4 alone, and for the stronger candle-powers, Plates 8, 6 and 4 together. The formula for the candle-power of a light at a distance R from the diffusing plate is $I = \frac{R^2}{r^2}C$ where r is the scale reading of the instrument when balance is obtained, and C, a constant depending on the secondary standard used and the diffusing plate inserted in the instrument at the time.

Since the secondary standard was not changed and the value of R remained fixed at 730 mm., two constants were found — C' when Plate 4 was used, and C'' when Plates 8, 6 and 4 were used, the value of R^2 being combined with C in the above formula.

These constants were:—

$$C': \text{Log} = 5.2988$$
$$C'': \text{Log} = 6.2053$$

It was then in any particular case simply necessary to subtract from the Log C' (or C''), the Log of r^2, when the corresponding candle-power was at once obtained.

In fact, however, the procedure was a bit more complex because of the difference in color between the secondary standard and the lamp under test. This type of Photometer is fitted with two extra eye diaphragms, one of red and the other of green glass, the particular hue of the glass being carefully chosen. Suppose the candle-power of a light is measured through the green glass and found to be Gr, similarly through the red glass it is found to be R, we find the ratio $\frac{Gr}{R}$; look up in a table supplied with the instrument, a factor k corresponding to this ratio, and the product kR is the true value of the candle-power required.

It may be of interest to see how a result thus obtained will check the spectrophotometer: thus I measured the candle-power of a certain mantle covered with a thin, white, opal globe and found it to be 59.4 candles; when covered with a similar pink opal globe the candle-power was 43.2, the loss of light being 27.3%: $\left(\frac{59.4 - 43.2}{59.4}\right)$

I then found with the spectrophotometer the curve (A) of ratio of intensity at different wave lengths of the white shaded mantle to the naked mantle, and the similar curve (B) for the pink shaded mantle to the naked mantle. By planimetering, the mean ordinate of curve A was found to be 148.2 units, and that of curve B was found to be 104.5 units, the loss according to these values being $\left(\frac{148.2 - 104.5}{148.2}\right)$ or 29.5 %, as compared with 27.3% above. I should say that this test was not made for a close check, but I was curious to see how close one could come in ordinary rapid work without any special precaution. Probably if the spectrophotometer readings had been extended over a wider range, the check would have been closer.

Spectrophotometer.— The results obtained with this instrument are purely relative, the figures given being invariably a ratio between the light under test and a specified standard. These results are fully as instructive for the purpose at hand as absolute values would be, while in view of the absence of any definite standard for such purposes and of the difficulty of getting the results on an absolute basis (say of energy), it was deemed best to leave them simply as ratios.

The constant of the instrument was determined as follows: The ratio between the two lights is $i = k \tan^2\phi$ where ϕ is the angle through which the Nicol prism in the eyepiece must be turned from its zero position in order that the two halves of the field may be of equal brilliancy, while k is a constant arising from the inequality to the two different light paths through the instrument.

The two halves of the field being illuminated by monochromatic light from the same source (a sodium flame screened with very uniform milk glass), the zero of the Nicol (for maximum darkness of the upper field) was found to be $\theta = 2° \; 1' \; 18''$. Again the setting for equal brilliancy of the two halves of the field was $\theta' = 49° \; 43' \; 0''$. Now it may be shown that $k = \text{cotan}^2 \; (\theta' - \theta)$, so that we have

$$k = 0.8286. \quad \text{Log}k = 9.9183 - 10.$$

The next step was the calibration of the scale of the instrument in wave-lengths. The Nicol eyepiece was removed and replaced by one which simply gave an image of the slit as in the ordinary spectroscope. The slit was illuminated with light of the desired wave-length, the line brought to the middle of the field and the corresponding scale reading observed.

In this way the following calibration was obtained:

TABLE 1.

LINE.	WAVE-LENGTH.	SCALE READING.
K_α	7680	11.53
Li	6708	12.05
H_α	6563	12.15
Na	5893	12 68
Tl	5349	13.29
H_β	4861	14.06
H_γ	4341	15.30
K_β	4046	16 31

The curve shown in Figure 1 was then plotted from these data and from this curve the points given in Table 2 were determined, these being the points at which measurements were made throughout the remainder of the work.

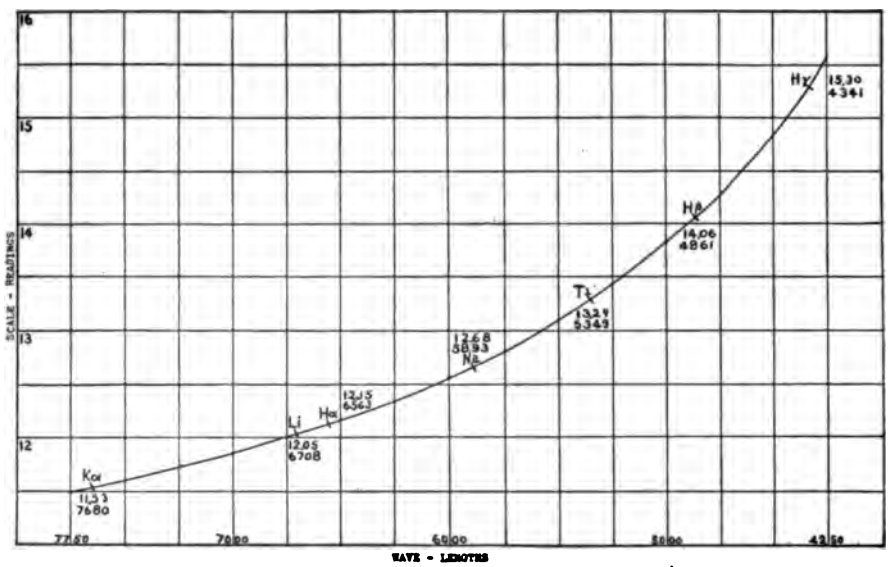

FIG. 1.

TABLE 2.

WAVE-LENGTH.	SCALE READING.	WAVE-LENGTH.	SCALE READING.
7750	11.49	5750	12.81
7500	11.62	5500	13.10
7250	11.75	5250	13.43
7000	11.88	5000	13.82
6750	12.03	4750	14.29
6500	12 19	4500	14.86
6250	12 37	4250	15.59
6000	12 57		

Gas Meter. — This was of the usual round pattern of wet meter, rated for 3 lights, as made by the Nathaniel Tufts Company. It was carefully calibrated by comparison with a number of large bottles whose volume was known. A volume of 20.46 cubic feet of gas, as measured by the bottles, was passed through the meter, which recorded 20.45 cubic feet. The meter was accordingly assumed correct within any limits required in this work.

RESULTS OF CANDLE-POWER TESTS.

The following Table 3 gives the gas consumption in cubic feet per hour, and corresponding candle-power of the mantles tested, together with an Argand and common flat flame burner, which are inserted for comparison:

TABLE 3.

Argand.		Flat Flame.		Mantle No. 1. Yusea.		Mantle No. 2. Majestic.		Mantle No. 3. Admiral.		Mantle No. 4.	
Gas.	C. P.	Gas.	C. P.	Gas.	C. P.	Gas.	C. P.	Gas.	C. P.	Gas.	C. P.
2.01	2.02	.93	2.54	1.25	3.30	1.41	2.18	1.80	2.19	1.20	2.20
2.37	3.58	1.50	4.64	1.75	33.20	1.95	7.31	1.98	4.30	1.44	3.26
2.64	4.54	2.22	7.31	2.05	49.50	2.37	22.00	2.22	17.70	2.04	9.59
2.85	5.93	3.00	9.33	2.45	68.90	2.55	38.90	2.64	37.80	2.49	24.50
3.27	8.06	4.02	11.80	2.85	80.50	2.79	57.50	3.00	51.20	3.23	56.20
3.72	16.70	5.34	12.70	3.20	86.00	3.72	85.00	3.78	79.50	3.84	75.20
4.53	22.00	6.18	11.60	4.00	78.50	4.32	76.30	5.16	67.70	4.98	66.80
5.70	26.70	6.90	11.40	4.85	67.00	5.04	68.50	5.82	60.40	5.70	54.90
5.82	30.30	7.68	11.20	5.85	59.50	5.82	60.40	6.30	57.50	6.36	45.90
6.78	33.10			6.53	56.60	6.36	57.50	6.60	56.20	6.96	41.30
6.96	36.40			7.44	55.50	6.96	55.50	6.96	51.20		
7.53	38.20										
7.92	40.10										
8.70	42.20										
9.00	43.10										
10.20	44.40										

Mantle No. 5.		Mantle No. 6.		Mantle No. 7.		Mantle No. 8.		Mantle No. 9.		Mantle No. 10.	
Gas.	C. P.	Gas.	C. P.	Gas.	C. P.	Gas.	C. P.	Gas.	C. P.	Gas.	C. P.
1.62	2.40	1.65	2.07	1.77	3.76	1.42	2.07	1.50	2.07	1.20	2.30
1.92	5.46	1.77	3.79	2.16	12.30	1.74	5.13	1.71	6.50	1.38	3.45
2.22	11.80	1.95	11.80	2.46	41.30	1.98	10.80	2.04	16.40	1.53	9.21
2.82	35.40	2.28	38.20	3.00	54.30	2.10	18.80	2.46	39.30	1.86	16.90
3.12	46.40	2.58	44.40	3.39	55.60	2.46	32.60	2.73	57.50	2.28	37.40
3.72	62.70	3.00	62.70	3.45	54.20	3.00	55.50	3.61	61.90	2.73	55.50
4.08	72.30	3.90	49.50	3.72	49.50	3.96	61.90	4.11	54.90	3.78	61.10
4.50	65.10	4.77	39.30	4.74	38.20	4.20	53.00	4.43	42.20	4.56	49.00
4.98	60.40	5.76	31.20	5.70	31.70	5.34	46.90	5.82	37.10	5.28	45.90
5.28	56.90	6.75	28.80	6.78	28.30	6.42	40.10	6.96	36.40	5.94	42.60
5.70	51.20			7.50	27.40	7.14	38.20			6.96	35.50

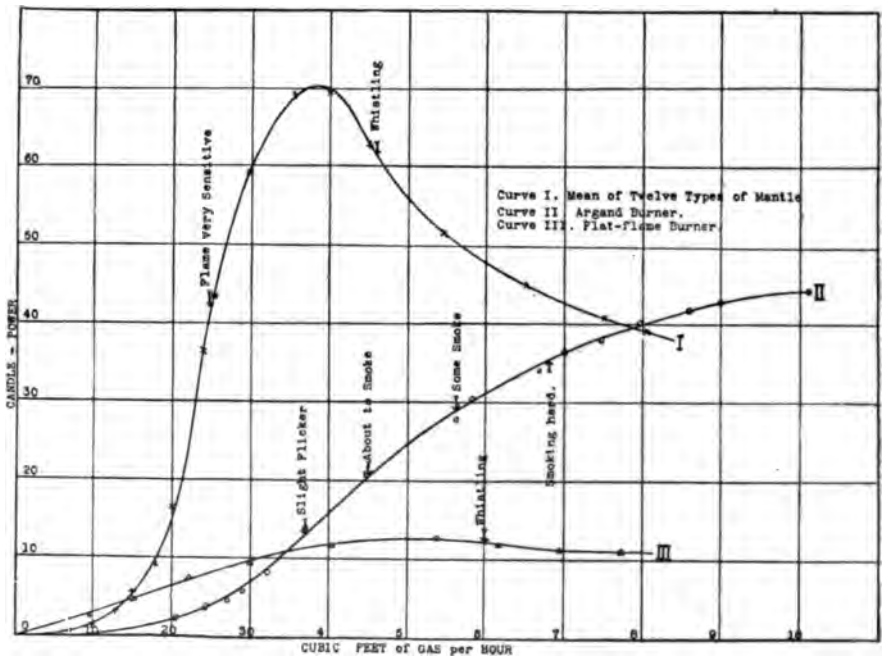

FIG. 2.

The same facts are shown in Figures 2, 3 and 4. Figure 2 shows the curve of the Argand, the flat flame, and the mean of the ten types of mantle. Figures 3 and 4 show the curves for the individual types. It is interesting to notice how the mantles separate into two groups

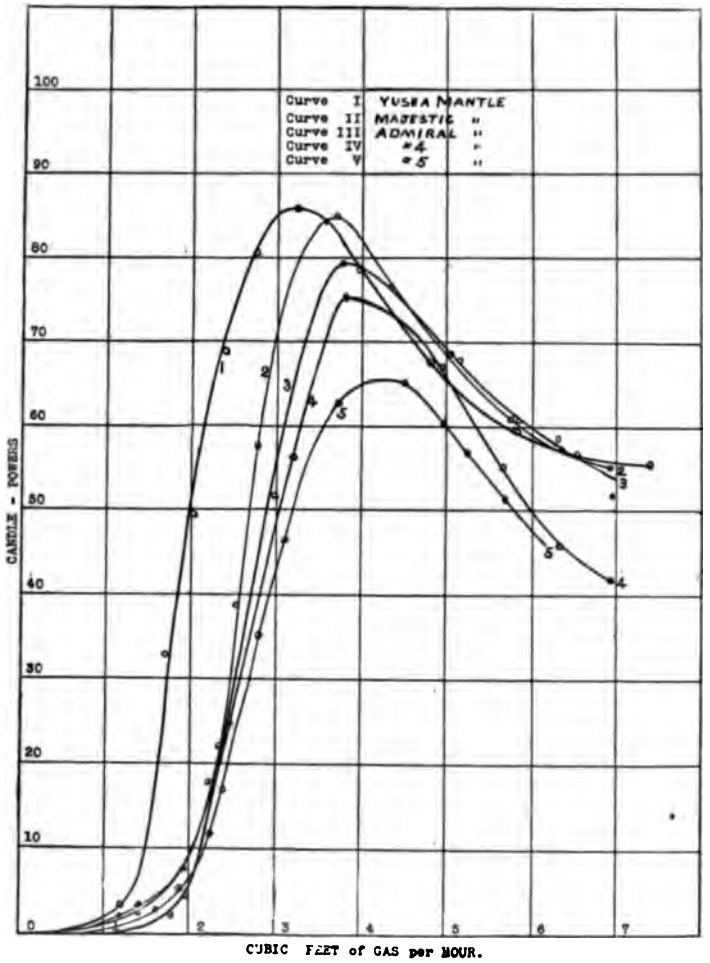

FIG. 3.

of five each, one having an average maximum of about 75, the other of about 60. This does not connect with either make, price, size of mesh, or number of threads — it may be due to correspondence in composition, but nothing appeared on the spectrophotometer to indi-

cate it, and I am unable to say at present that it is more than a coincidence.

It should be said that all of the mantles showed an increasing tendency with age to clog up with soot, some more rapidly than

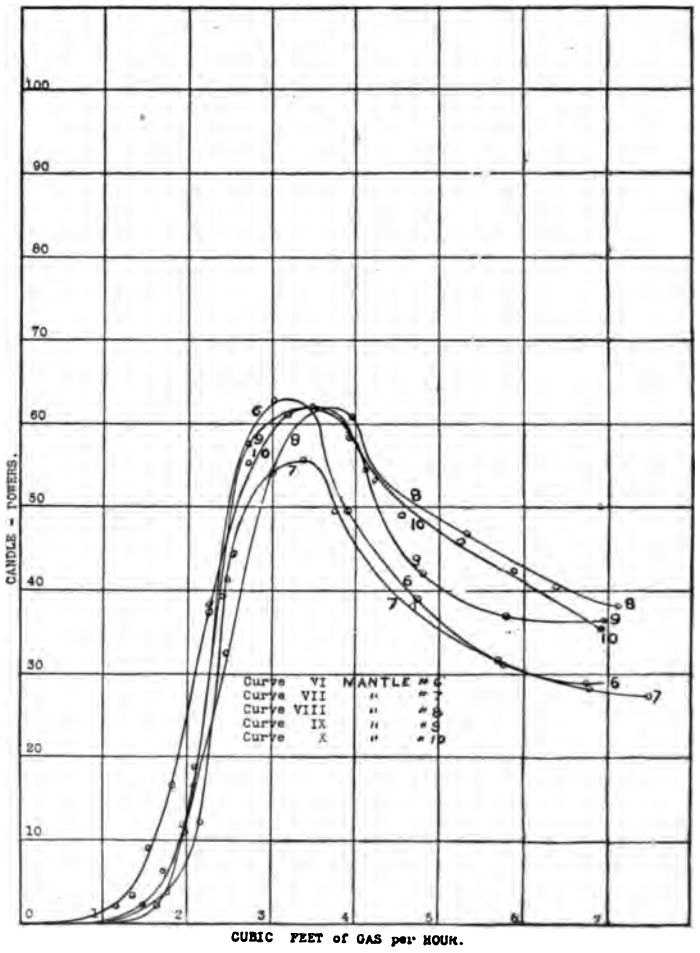

FIG. 4.

others, however. In the matter of handling, which of course is deleterious in the extreme after the mantle is once lighted, the Yusea and the Admiral seemed by far the most durable. Again, the matter of warping is an important point, and here the Yusea and Majestic led, with the Admiral a good third.

It may be also of interest to note that the flame invariably passed through a very sensitive state, so much so that frequently a sharp snap of the thumb and finger or a sneeze across the room would nearly or completely extinguish the light, and that this point occurred invariably when about three-quarters of the way up the steep ascent of the curve toward maximum brilliancy, which was reached shortly after the sensitiveness had fallen off, while about an equal distance beyond the maximum on the descending branch of the curve occurred the "whistling point," where the gas began to make a noticeable noise as it passed the burner.

The examination thus far seemed to show that the choice lay between the three mantles already named, with a possibility of Number 4 also, but this latter seemed very fragile and clogged badly, so that I finally discarded it; the other three were fully tested, with results now to be described.

Table 4 and Figure 5 show the results of the test for gas consumption and candle-power for the three selected mantles at the end of a 200 hours' life test.

TABLE 4.

Yuska Mantle.		Majestic Mantle.		Admiral Mantle.	
Gas.	C. P.	Gas.	C. P.	Gas.	C. P.
0.85	1.90	0.80	1.00	1.15	.60
1.36	10.50	1.28	2.10	1.70	7.00
1.90	33.20	1.80	16.20	2.20	17.80
2.54	60.40	2.45	37.80	2.50	31.00
3.25	69.30	3.22	61.50	3.00	49.20
3.87	68.00	3.90	62.50	3.60	57.80
4.53	64.10	4.50	54.20	4.28	55.50
5.20	58.50	5.15	46.50	5.12	48.80
5.74	55.00	5.68	41.50	5.60	43.50
6.22	54.20	6.17	40.50	6.10	39.00

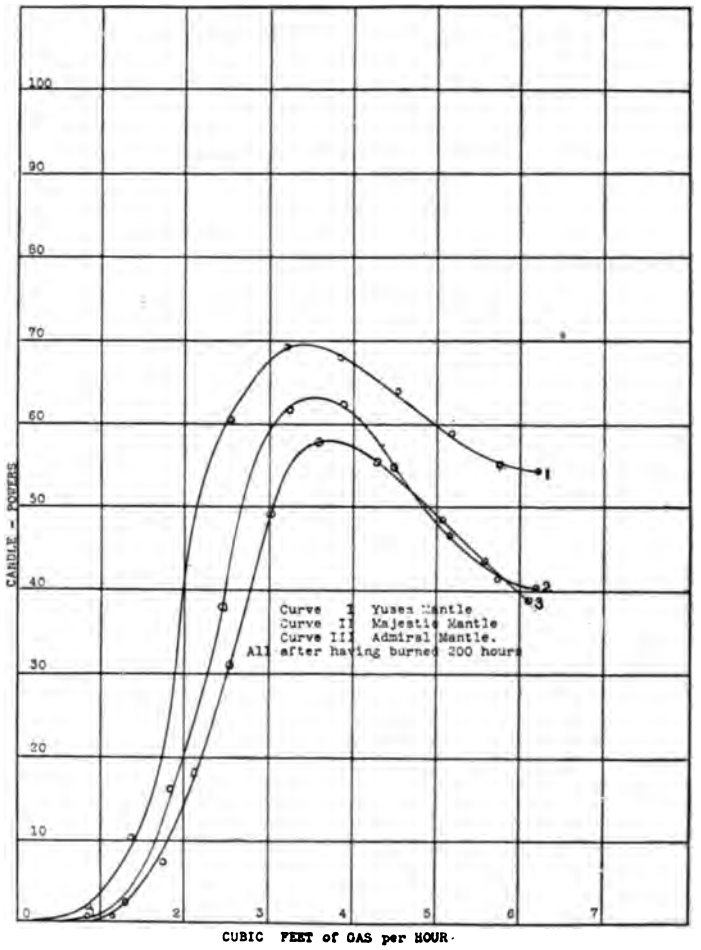

FIG. 5.

It is well known that mantles, though they may give a very white light at first, immediately begin to change in color, some more rapidly than others and some going further than others in the direction of a sickly greenish hue, which is exceedingly disagreeable, the majority tending toward a hue on the blue side of the green, but some toward one on the yellow side. The only way of telling what and how great change takes place is to study the mantle throughout a lengthy period with the spectrophotometer.

The plan followed was to take the two matched mantles selected as previously described, and having chosen one as a standard, to place it in position and adjust the burner and cocks in the piping so that after having warmed up, it consumed gas at the proper rate. This mantle was burned as little as possible — in all a total of less than four hours.

The other, or test, mantle was put in position and burned steadily for 200 hours. It was compared with the standard after having burned 5, 10, 20, 40, 50, 80, 100, 120, 140, 160, 180, and 200 hours; at

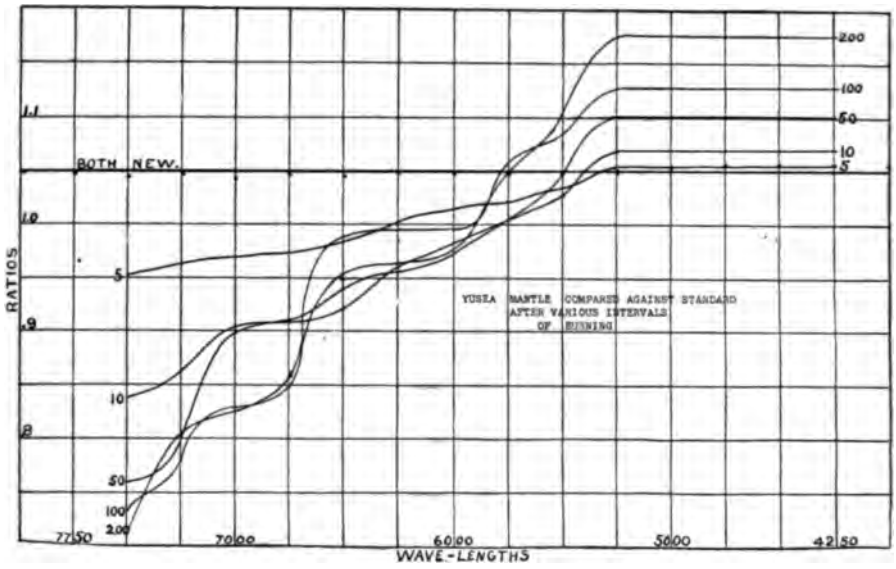

FIG. 6.

these times it was also tested for candle-power at the rate of gas consumption which the previous test had shown to give the maximum light, and at the end of the 200 hours it was again examined for candle-power with changing gas consumption, for comparison with the measurements made when it was new.

Of course it should be noted that the standard mantle itself changes somewhat, and that accordingly the curves are not exactly what they would be if it remained constant; however, I examined one mantle pretty carefully, and came to the conclusion that it was hardly worth while to attempt to correct for this change, as its effects were not very marked.

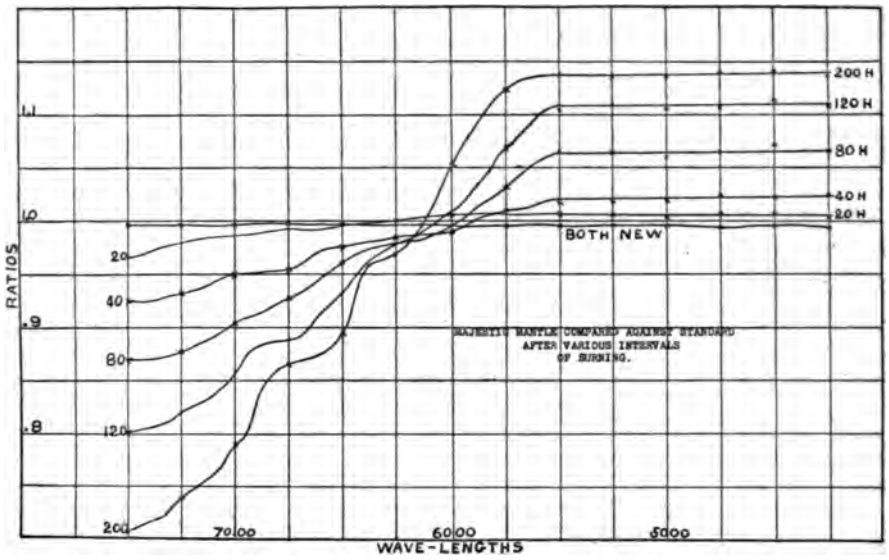
200 H
120 H
80 H
40 H
20 H
BOTH NEW
1.1
1.0
.9
.8
RATIOS
20
40
80
120
200
MAJESTIC MANTLE COMPARED AGAINST STANDARD
AFTER VARIOUS INTERVALS
OF BURNING.
7000
6000
5000
WAVE-LENGTHS

FIG. 7.

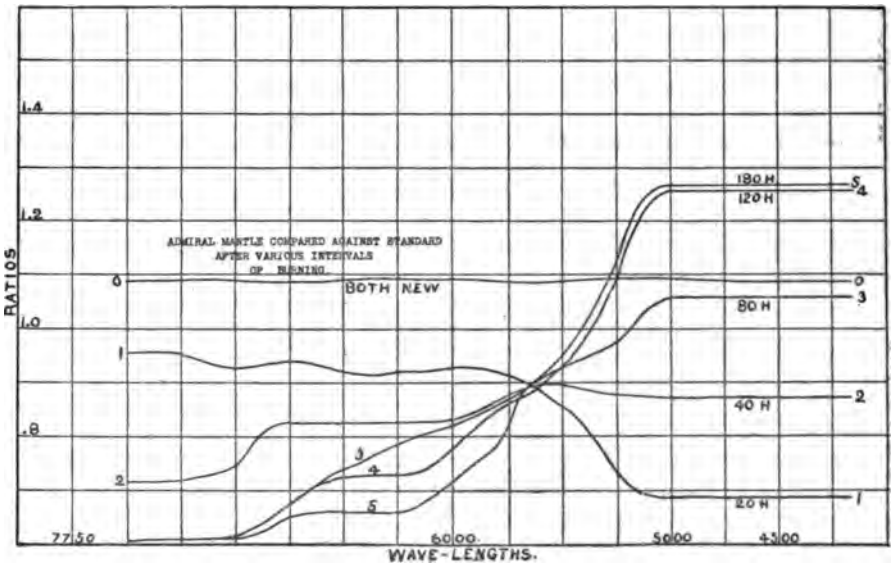
1.4
1.2
1.0
.8
RATIOS
ADMIRAL MANTLE COMPARED AGAINST STANDARD
AFTER VARIOUS INTERVALS
OF BURNING.
BOTH NEW
0
1
2
3
4
5
180 H
120 H
80 H
40 H
20 H
7750
6000
5000
4300
WAVE-LENGTHS.

FIG. 8.

It hardly seems worth while to burden this article with tables of figures obtained in the tests with the spectrophotometer, especially as the plots show the relation of the curves very clearly, and it is the nature of the changes rather than the particular values obtained which is of interest here.

Figure 6 gives the curves for the Yusea mantle, showing the changes at five selected intervals; these show clearly the progressive character of the changes and are sufficient for the purpose. The curves for the remainder of the intervals would simply serve to complicate the figure without adding anything material.

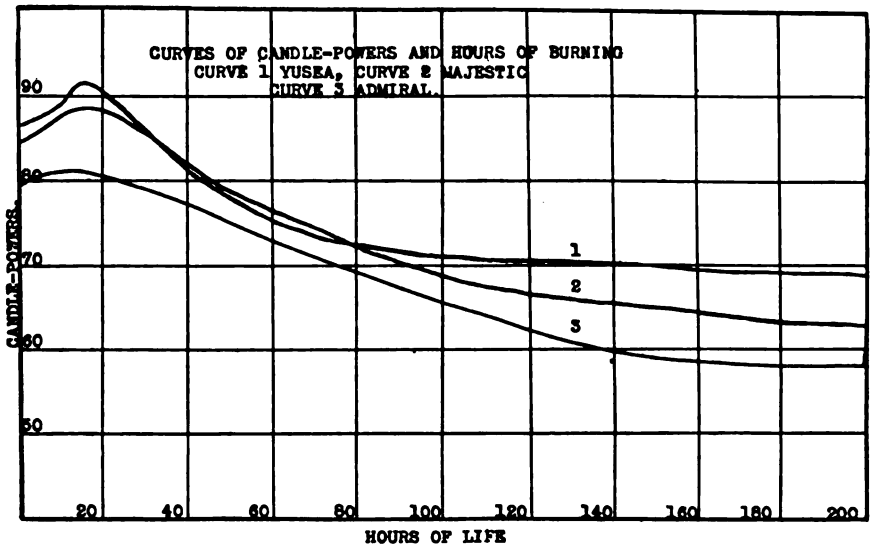

FIG. 9.

Figure 7 gives a similar set of curves for the Majestic mantle, and Figure 8 for the Admiral.

It will be noticed that there is in each case a point in the yellow or orange where the curves intersect, although this is much more marked in the Majestic and Admiral than in the Yusea. In this latter the curves weave in together at several points, and in this connection it is interesting to note that the Yusea is a mantle tending toward a yellowish green, while the other two both tend toward a bluish green.

The curves of Figure 9 are the candle-power variations with hours of burning for the three mantles. Each of these curves shows a

maximum after the mantle has burned a few hours, and from thence on a steady decrease, which, however, is hardly appreciable after the first hundred hours. This change, as well as those affecting the color of the light emitted, is probably due to the varying volatility of the chemical constituents of the mantle, so that in the earlier portion of its life the composition is changing rapidly, and later on more and more slowly.

As a result of this work I settled upon the Yusea as the best mantle for use in important places, with either the Majestic or Admiral in less important ones; I should choose the Majestic to replace the Yusea when it was not desired to use as high a priced mantle as the Yusea, and I should use the Admiral instead of the Majestic in places where I feared rough usage, as, although not quite so efficient, it appears to stand hard treatment rather better.

Of course the mantle, of whatever style it might be, ought not to be used without some pattern of diffusing shade, and this shade (or the chimney inside of the shade) ought to be tinted so as to correct so far as possible for the peculiar hue of the light, changing it over either to a fairly good white or to the more usual hue of artificial house illuminants.

Tests on Shades and Chimneys.

I had a selection of nine globes of the shape of an egg, open at both ends, as follows:

2nd. Prismatic glass (vertical inner ribs).
3rd. White Holophane glass.
4th. Pink Holophane glass.
5th. Robin's Egg Blue, fluted opal glass.
6th. Pale Green, fluted opal glass.
7th. Orange Yellow, fluted opal glass
8th. Rose Pink, fluted opal glass.
9th. Ruby, fluted frosted glass.
10th. White, fluted opal glass.

Also six chimneys (such as I could find in the Boston office of the Welsbach Company), as follows: —

2nd. Thin Greenish-blue glass.
3rd. Amber glass.
4th. Rather thick White opal glass.
5th. Dark Green glass.

6th. Dark Red glass.

7th. Dark Blue glass.

None of these chimneys would be of value except for producing color-effects in advertising, etc., but it is of interest to see what their use means in waste of light.

As a standard of white light for interior use I chose the Nernst lamp fitted with a thin globe of frosted glass for diffusion. In order that one may see about what this light is compared with various others, I give in Figure 10 some curves of comparison. In obtaining these curves the standard slit of the photometer was turned toward the clear overhead sky, near noon on a day in early spring, so that the light falling on the slit was about what would fall on a sheet of paper shaded from the direct rays of the sun and far away from any source of colored reflected light, such as foliage, brick walls, etc.

If this is assumed as the unit for each wave length, then the curves of Figure 10 show the relative proportion of light of each wave length present in the different flames: —

Curve 1. The Yusea mantle at 11.30 A.M.

Curve 2. The Acetylene flame at 11 A.M.

Curve 3. The Argand burner at 12 M.

Curve 4. The Nernst lamp at 12.25 P.M.

Curve 5. The Enclosed 110 V. D.C. arc lamp, with thin opal inner globe and clear outer, at 1 P.M.

Curve 6. The same Yusea mantle at 5 P.M.

This last is interesting as showing how the sky light has changed in character toward sunset.

These curves are purely relative, and the scale of ordinates merely furnishes a convenient scale for comparing the curves. It does not mean, for instance, that the acetylene flame has thirty-one times as much deep red in it as the sky, and about an equal amount of violet, but only that the ratio of red to violet is about 31 : 1, whereas, in this particular sky light, by hypothesis it was 1 : 1.

It will be seen that the Nernst, Acetylene, and Argand are nearly the same from $\lambda = 4250$ to $\lambda = 6000$, that the Acetylene contains rather more light of the hue of the α line of hydrogen than either Nernst or Argand, while the Argand contains more light of the deep red hue of the neighborhood of the α line of potassium than they do.

The peculiar color of the Welsbach is indicated by the preponderance of hues due to the shorter wave-lengths over the others, there being, for instance, about double the quantity of light of the hue of

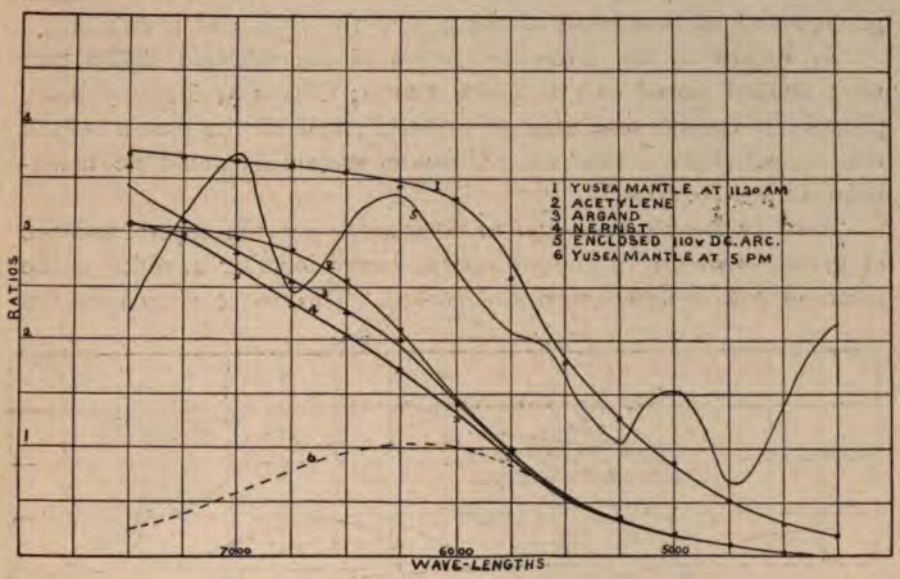
1 YUSEA MANTLE AT 11.30 AM
2 ACETYLENE
3 ARGAND
4 NERNST
5 ENCLOSED 110v DC. ARC.
6 YUSEA MANTLE AT 5 PM
RATIOS
WAVE-LENGTHS
7000
6000
5000

FIG. 10.

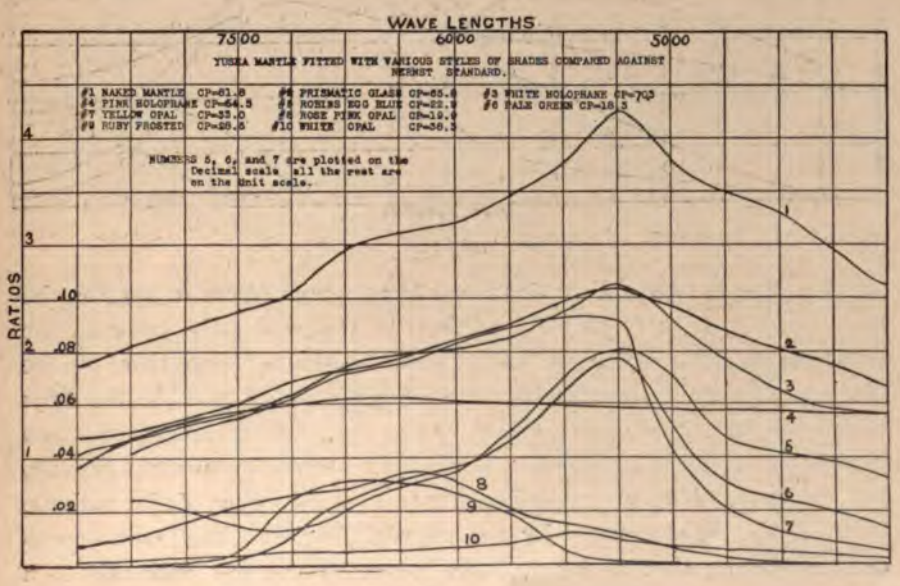
WAVE LENGTHS
7500
6000
5000
YUSEA MANTLE FITTED WITH VARIOUS STYLES OF SHADES COMPARED AGAINST NERNST STANDARD.
#1 NAKED MANTLE CP=61.8
#4 PINK HOLOPHANE CP=64.5
#7 YELLOW OPAL CP=33.0
#9 RUBY FROSTED CP=20.5
#5 PRISMATIC GLASS CP=65.6
#8 ROSINS EGG BLUE CP=22.0
#6 ROSE PINK OPAL CP=19.0
#10 WHITE OPAL CP=36.3
#3 WHITE HOLOPHANE CP=74.5
#2 PALE GREEN CP=18.3
NUMBERS 5, 6, and 7 are plotted on the Decimal scale all the rest are on the Unit scale.
RATIOS
.10
.08
.06
.04
.02

FIG. 11.

the sodium flame, about three times as much of the hue of thallium green, and four times that of the β line of hydrogen.

In Figure 11 are given the curves of the different shades that were studied placed over a Yusea mantle; Curves 5, 6 and 7 being plotted on the decimal scale of ordinates, and all the others on the unit scale. These three curves, unless magnified, would lie underneath Curve 10 entirely.

None of the shades begin to compensate for the superabundance of green shown by the naked mantle, except Number 4, which is the mean of half a dozen pink Holophanes. This shade gives almost a

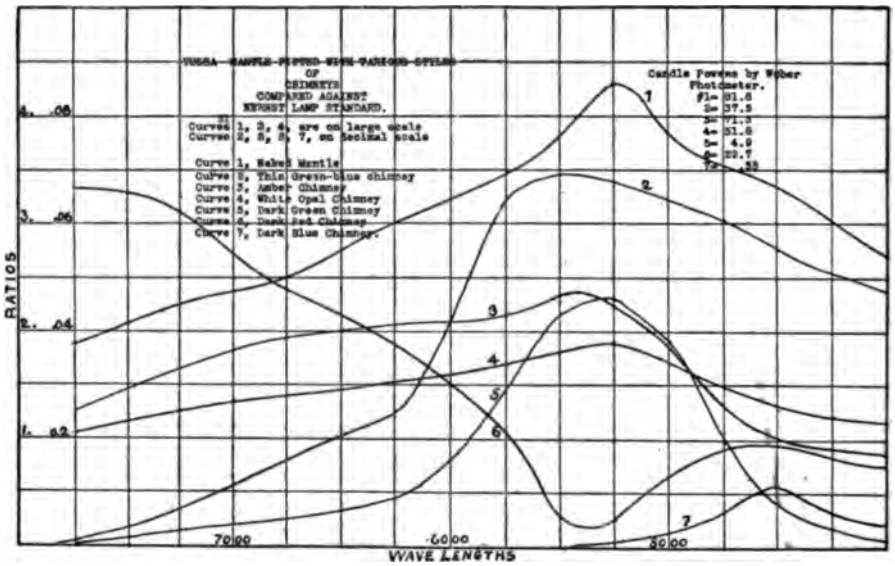

FIG. 12.

straight line between $\lambda = 6750$ and $\lambda = 4500$. Were it not for the slight rise at $\lambda = 6250$ and the drop in the violet, the color of the transmitted light would be hardly distinguishable from that of the Nernst. As it is, there is the faintest suspicion of pink in the light which can hardly be distinguished by the eye. Unfortunately it seems impossible at present to ensure absolute uniformity in this tint of pink, but the shades hardly vary sufficiently to count, in view of the variable color of the light emitted by the mantle, so that I feel quite confident in stating that so far as I am aware the nearest approach to a good quality of white light with the Welsbach system is to be attained by the use of this combination.

The following Table gives the candle-powers found by the Weber Photometer, and hence a measure of the light lost; but it should be understood that since the candle-power given is horizontal and not mean spherical, the two Holophanes cannot be directly compared with the others, since these two differ widely from the others in their action on the light.

TABLE 5.

Number of Curve.	Shade.	Candle-Power.	Per Cent. Loss.
1	Naked Mantle.	81.80	
2	Prismatic Glass.	65.80	19.6
3	White Holophane.	70 30	14 1
4	Pink Holophane.	64.30	20.8
5	Robin's-Egg Blue Opal.	22.90	72.2
6	Pale Green Opal.	18 30	77.8
7	Yellow Opal.	33.00	59.7
8	Rose Pink Opal.	19.90	75.6
9	Ruby Frosted.	28.50	65.2
10	White Opal.	38 30	53 2

Figure 12 is a plot for the chimneys examined. Curves 1, 3 and 4 are on the unit scale, the others on the decimal scale. Table 6 gives the candle-power transmitted.

TABLE 6.

Number of Curve.	Chimney.	Candle-Power.	Per Cent. Loss.
1	Naked Mantle.	81 80	
2	Thin Green Blue.	37.50	54.2
3	Amber.	71.30	12.8
4	White Opal.	51.80	36.7
5	Dark Green.	4.90	92 8
6	Dark Red.	22 70	72.3
7	Dark Blue.	0 35	99.6

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